MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. LVIII. No. 1. November 1897.

ADMISSION OF LADIES TO THE ORDINARY MEETINGS OF THE SOCIETY.

The attention of Fellows is called to the fact that ladies are only admitted to the Ordinary Evening Meetings of the Society by special invitations of the President, sanctioned by the Council. The invitations are issued at the commencement of each Session.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1897 TO NOVEMBER 1898.

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MONTHLY NOTICES

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ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. NOVEMBER 12, 1897. No. 1

Sir R. S. BALL, LL.D., F.R.S., President, in the Chair.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Captain E. J. Griffin, Commander of U.S.S. Co.'s S. S. *Moor*, Lieutenant R.N.R. (proposed by Captain D. Forbes);
J. Nevil Maskelyne, 88 Trinity Road, Upper Tooting, S.W. (proposed by E. W. Maunder);
Ambrose Swasey, Cleveland, Ohio, U S.A. (proposed by Sir R. S. Ball);
John Vaughan, Sub-Lieutenant R.N.R., Commander, China Navigation Company, Shanghai, and 42 Aubert Park, Highbury, London, N. (proposed by Thomas Mackenzie);
Thomas Emley Young, B.A., President of the Institute of Actuaries, 108 Evering Road, Stoke Newington, London (proposed by G. F. Hardy).

One hundred and ninety-four presents were announced as having been received since the last meeting, including, amongst others :—

J. C. Adams, Scientific Papers, vol. i., presented by the Adams Memorial Committee ; A. Auwers, Fundamental Catalog für Zonenbeobachtungen am südhimmel ; A. Auwers, Tafeln zur

Reduction von südlichen Sterncatalogen; S. C. Chandler, Synthetical statement of the theory of polar motion; J. C. Clancey, Aid to land surveying; H. Deslandres, Spécimens de photographie astronomique; E. S. Holden, Memorials of W. C. and G. P. Bond; G. Leveau, Tables de Vesta; S. Newcomb, New determination of precessional motion; J. Palisa, Sternkarten Nos. 3–7; F. C. Penrose, Orientation of Greek temples:—the above works presented by the authors. British Almanac and Companion, 1859–60, presented by Mr. Chambers; Moore's Almanac, 1805–64, presented by Rev. S. J. Johnson. Harvard Observatory Annals, vol. xxvi.; Nice, Observatoire, Annales, tome vi.; Paris, Observatoire, Catalogue des Etoiles, &c., tome iii.—presented by the Observatories; Astronomische Gesellschaft, Publicationen No. xxi., presented by the Society.

Series of photographs of the Moon and *Jupiter* (negatives and enlargements on glass), presented by the Lick Observatory; two photographs of the Moon, taken at the Royal Observatory, Greenwich, presented by the Astronomer Royal; Lantern slide of the nebula in *Orion*, presented by Mr. Wilson; Photographs of a meteor track, presented by Professor Barnard.

Address to Her Majesty the Queen on the completion of the Sixtieth Year of Her Reign.

The following is the text of the Address to Her Majesty which was received on Her behalf by H.R.H. the Prince of Wales, at St. James's Palace, on 1897 July 21:—

"To the Queen's Most Excellent Majesty.

"May it please your Majesty,—We, the President, Council, and Fellows of the Royal Astronomical Society, humbly beg to approach Your Majesty with the tender of our sincere and respectful congratulations on the happy completion of the sixtieth year of Your Majesty's most auspicious reign.

"Sixty years ago Your Majesty was graciously pleased to become the Patron of our Society. In approaching Your Majesty on that occasion our Society ventured to express the hope that Your Majesty's reign 'would be distinguished for the advancement of Astronomy, as well as of every other branch of Science, and for the enjoyment, under Divine Providence, of every earthly blessing.'

"When we see how abundantly these loyal wishes have already been fulfilled, we desire to express our deep appreciation of the interest and sympathy that Your Majesty has always manifested in the intellectual well-being of Your subjects; and on behalf of all those within the wide limits of Your Majesty's

Empire who are interested in the development of Astronomy we gratefully acknowledge the benefits we have enjoyed during the long continuance of Your Majesty's reign, and pray that for many years Your Majesty may be spared to rule over us."

The Address was presented by the President (Sir R. S. Ball) and one of the Secretaries (Professor H. H. Turner), and the following reply was handed to the President :—

"On behalf of the Queen, my dear Mother, I thank you for your loyal and dutiful Address and for the affectionate congratulations which you tender on the completion of the sixtieth year of Her reign.

"It is a source of profound joy to the Queen to receive the expressions of devotion to Her person and family which are offered by Her subjects throughout the Empire. She is gladdened by the thought that the sixty years of Her reign have been years of progress in knowledge and of increase in prosperity; and She prays that, by the blessing of Almighty God, She may always live in the hearts of Her loving and beloved people."

The President has since received the Jubilee Medal from Her Majesty.

Note on a result concerning Diffraction Phenomena used by Professor Wadsworth in several recently published papers. By H. F. Newall, M.A.

Professor Wadsworth has recently published in a great number of journals (*Observatory*, *Knowledge*, *Astrophysical Journal*, *Monthly Notices of R.A.S.*, *Astronomische Nachrichten*) remarks concerning the performance of various lenses with respect to photographic delineation of faint nebulæ, &c. Underlying these remarks is a misinterpretation of a result obtained by Stokes in 1853, and it seems desirable to point out the error.

Stokes gave (*Trans. R.S. Edin.* xx. 1853) a general analytical verification of a result obtained for certain special cases by Kelland (*Trans. R.S. Edin.* xv.). These results were reached by Kelland in a comparison of the total quantity of light coming from a distant point and falling on an object glass, with the total quantity of light in the resulting diffraction pattern, which forms the image of the distant point. It was at that time a question whether any of the energy was lost as *light*, or whether light was simply transferred from dark rings in the diffraction pattern and piled up in the bright rings without any loss.

Stokes and Kelland showed that the total quantity of light in the diffraction pattern (viz. $\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \mathrm{I}\ d\xi\ d\eta$ in the usual

notation) was equal to the total quantity incident upon the object glass, viz. $\int\int d\,x\,dy$=area of object glass, where the intensity, *i.e.* the quantity of light per unit area, incident on the object glass is unity.

The incident light was regarded as coming from a *single distant point*, so that the wave front on the object glass was plane, with uniform distribution over it.

The integral was taken over the diffraction pattern nominally between the limits $-\infty$ and $+\infty$ for both ξ and η, but practically the quantity of light contributed by an element of area in the focal plane falls off very rapidly as the distance of the element from the centre of the diffraction pattern increases.

The meaning of the infinite limits is entirely different in the case which Professor Wadsworth deals with. *Each point* in the uniformly illuminated sky considered by him contributes to the illumination of the photographic plate a quantity of light which is proportional to the area of the object glass; but *the scale of the photograph of the sky* depends on the focal length of the object glass.

The criticism and attempted explanation which Professor Wadsworth gives of practical results obtained with large and small reflectors and refractors falls to the ground. Professor Wadsworth's conclusions are incorrect.

In the *Astrophysical Journal*, vol. vi. 1897 August, p. 132, it is clear that there is discontinuity in Wadsworth's solutions. On p. 132 he arrives at the correct result that for large finite illuminated surfaces the intensity on the photographic plate is proportional to $\frac{A^2}{f^2}$. But on the following page he reaches the incorrect result that for the large sky the intensity is proportional to A^2.

On the Apparent Diurnal Motion of Stars in relation to the Adjustment of the Polar Axis of a Telescope. By C. Davidson, Royal Observatory, Greenwich.

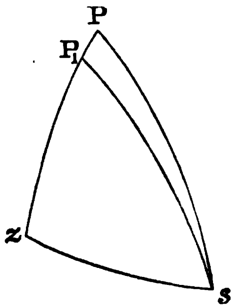
(*Communicated by W. H. M. Christie, Astronomer Royal.*)

In *Monthly Notices*, vol. 57, No. 2, Professor Rambaut has discussed the variable effect which refraction has on the apparent motion of stars, and proposes a method by which an equatorial telescope may be kept accurately pointed on a star by introducing corresponding variations into the rate of the driving clock.

In this paper, however, he does not take into account any want of adjustment of the polar axis of the telescope. If this does not point to the Pole, an additional variation in the rate of

the driving clock will be required to correct for this. At Greenwich the polar axes of the photographic equatorials have been adjusted so that when the instrument is pointed to, or near, the Pole, and the clock is rated to sidereal time, no elongation of the images occurs. This implies that the polar axis of the telescope does not point to the true, but to the apparent Pole (as affected by refraction). That this is the case can be easily seen by making the supposition that there is a star at the Pole. This will be seen at the apparent Pole, and to obtain a round image of it the polar axis of the equatorial must be pointed to it.

When an equatorial is adjusted in this manner the alteration required in the rate of the clock in order to keep the telescope accurately pointed is very different from that required when refraction only is considered, and does not become infinite at the Pole, which would not be the case if the axis were adjusted to the true Pole. But even if a telescope is not adjusted in this way, as the polar axis is rarely pointed accurately to the true Pole, it may be of interest to consider the effect of this error.



Leaving out refraction and considering only the elevation of the Pole, if P is the true, P_1 the instrumental Pole, z the zenith, and s a star,

Then

$P\,P_1$ is the error of elevation $= e$.

$z\,P\,s$ is the hour angle of the star $= h$.

$$P\,s = \frac{\pi}{2} - \delta.$$

$z\,P_1\,s$ is the hour angle as shown by the telescope.

Therefore

$$\Delta h = e \sin h \,.\, \tan \delta.$$

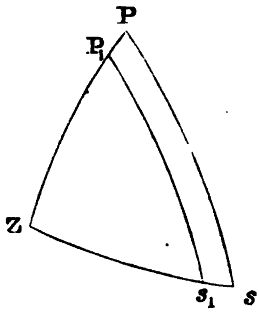
And

$$\frac{d\,\Delta\,h}{d\,h} = e \cos h \,.\, \tan \delta\,,$$

which, e being known, may be easily applied as a correction to Professor Rambaut's table.

But I wish to consider at greater length the result when, as

at Greenwich, P_1 is also the apparent Pole, combining with it the variation due to refraction.



As before z, P, and s are the zenith, pole, and a star.
P_1 the apparent and instrumental Pole.
s_1 the star as affected by refraction.
Then

$$z\,P = \text{colatitude} = c,$$

$$z\,s = \text{zenith distance} = z,$$

$$P\,s = \frac{\pi}{2} - \delta,$$

and

$$P\,s\,z = \text{angle } Q.$$

Then

$$\Delta h = -\Delta c \sin h \,.\, \tan\delta + \Delta z \frac{\sin h \,.\, \sin c}{\sin z \,.\, \cos\delta}.$$

Putting $\Delta c = -k \tan c$,
and $\Delta z = -k \tan z$, where k is the constant of refraction; this becomes

$$\Delta h = -k \sin h \,.\, \tan c \tan z \,.\, \cos Q,$$

and the change of rate is given by

$$\frac{d\Delta h}{dh} = -k\,(\tan c \,.\, \cos h \tan z \,.\, \cos Q + \sin^2 c \,.\, \sin^2 h \sec^2 z).$$

The computation of tables from this formula is simplified by the introduction of an auxiliary angle θ defined by

$$\tan\theta = \tan c \,.\, \cos h,$$

for

$$\tan z \,.\, \cos Q = \frac{1 - \tan c \tan\delta \,.\, \cos h}{\tan\delta + \tan c \,.\, \cos h}$$
$$= \cot(\delta + \theta),$$

and

$$\cos z = \frac{\cos c \sin (\delta + \theta)}{\cos \theta},$$

and the formula then becomes

$$\frac{d\Delta h}{dh} = -k \left\{ \tan \theta \cot (\delta + \theta) - \frac{\tan^2 c \,.\, \sin^2 h \cos^2 \theta}{\sin^2 (\delta + \theta)} \right\}.$$

When special cases are considered some interesting modifications occur in the formula.

On the meridian it simplifies to

$$\frac{d\Delta h}{dh} = -k \tan c \tan z,$$

and at 6^{hrs} from the meridian

$$\frac{d\Delta h}{dh} = -k \tan^2 c \,.\, \operatorname{cosec}^2 \delta.$$

Near the Pole the rate is

$$+ k \tan^2 c \cos 2h.$$

It should be noted that this is finite, and that the elongation of the image of any star will be infinitesimal.

It will be observed that the effect of this adjustment disappears at the equator, and also at six hours from the meridian, leaving the effect due to refraction only, and is greatest near the Pole on the meridian, where the effect of refraction is eliminated.

Table I. exhibits the results obtained, in daily rates, + signifying a gaining and − a losing rate.

TABLE I.

Hour Angle.

Decl. °	0h s	1h s	2h s	3h s	4h s	5h s	6h s	7h s	8h s	9h s	10h s	11 s	12h s
−20	−57·3	−65·6	−104·6										
15	−44·1	−49·0	− 69·7										
10	−35·3	−38·5	− 51·3	−91·2									
− 5	−29·0	−31·2	− 39·9	−63·9									
0	−24·1	−25·8	− 32·1	−48·1	−96·3								
+ 5	−20·2	−21·6	− 26·5	−38·0	−68·1								
10	−16·9	−18·1	− 22·1	−30·9	−51·3	−112·7							
15	−14·2	−15·2	− 18·6	−25·7	−40·5	− 77·9							
20	−11·7	−12·7	− 15·7	−21·7	−33·1	− 57·7	−130·5						
25	− 9·6	−10·4	− 13·2	−18·5	−27·7	− 45·0	− 85·5						
30	− 7·6	− 8·4	− 11·1	−15·9	−23·6	− 36·5	− 61·1	−123·0					
35	− 5·7	− 6·5	− 9·1	−13·6	−20·4	− 30·5	− 46·4	− 75·5					
40	− 3·9	− 4·8	− 7·4	−11·7	−17·9	− 26·2	− 37·0	− 51·4	−71·5				
45	− 2·2	− 3·1	− 5·7	−10·1	−15·8	− 22·9	− 30·5	− 37·7	−41·0	−31·8			
50	− 0·5	− 1·4	− 4·2	− 8·5	−14·1	− 20·3	− 26·0	− 29·2	−26·2	−10·7			
55	+ 1·2	+ 0·2	− 2·7	− 7·2	−12·7	− 18·4	− 22·8	− 23·8	−18·2	− 2·7	+23·3	+51·8	+64·8
60	+ 2·9	+ 1·8	− 1·3	− 6·0	−11·5	− 16·8	− 20·4	− 20·1	−13·6	+ 0·6	+20·9	+40·4	+48·7
65	+ 4·6	+ 3·5	+ 0·1	− 4·8	−10·5	− 15·6	− 19·5	− 17·6	−10·8	+ 1·8	+18·2	+32·6	+38·5
70	+ 6·4	+ 5·2	+ 1·5	− 3·7	− 9·6	− 14·7	− 17·3	− 15·8	− 9·2	+ 2·1	+15·6	+26·9	+31·3
75	+ 8·3	+ 6·9	+ 3·0	− 2·7	− 8·9	− 14·0	− 16·4	− 14·7	− 8·2	+ 1·9	+13·4	+22·4	+25·9
80	+10·4	+ 8·8	+ 4·5	− 1·8	− 8·3	− 13·5	− 15·7	− 13·9	− 7·7	+ 1·4	+11·3	+18·9	+21·7
85	+12·7	+10·9	+ 6·0	− 0·8	− 7·9	− 13·3	− 15·4	− 13·4	− 7·6	+ 0·8	+ 9·4	+15·8	+18·2
+90	+15·3	+13·2	+ 7·6	− 0·0	− 7·6	− 13·2	− 15·3	− 13·2	− 7·6	0·0	+ 7·6	+13·2	+15·3

The following table is a comparison of the necessary changes in the clock rate near the meridian when the polar axis is adjusted to the true Pole with those when it is adjusted to the apparent Pole :—

TABLE II.

Decl.	Rate on the meridian polar axis adjusted to the True Pole.	Apparent Pole.	Decl.	Rate on the meridian polar axis adjusted to the True Pole.	Apparent Pole.
°	s	s	°	s	s
−20	−52·0	−57·3	+55	−25·6	+1·2
15	40·5	44·1	60	29·4	2·9
10	32·7	35·3	65	35·6	4·6
−5	27·8	29·0	70	44·5	6·4
0	24·3	24·1	75	63·3	8·3
+5	22·0	20·2	80	−94·0	10·4
10	20·3	16·9	85	...	12·7
15	19·2	14·2	90	...	15·3
20	18·6	11·7	85 S.P.	...	18·2
25	18·3	9·6	80 S.P.	+121·9	21·7
30	18·4	7·6	75 S.P.	93·4	25·9
35	18·9	5·7	70 S.P.	76·9	31·3
40	19·6	3·9	65 S.P.	70·5	38·5
45	21·1	2·2	60 S.P.	72·0	48·7
+50	−22·8	−0·5	55 S.P.	+79·7	+64·8

As regards the change in the apparent declination of a star due to this adjustment

$$\Delta\delta = -\Delta c \cos h,$$

and

$$\frac{d\Delta\delta}{dh} = +\Delta c \sin h,$$

h being the westerly hour angle.

This change will be seen to vanish on the meridian, but, on either side of it, will go in an opposite direction to that due to refraction.

The Great Equatorial Current of Jupiter.
By A. Stanley Williams.

I. *On the Rate of Rotation in* 1897.

Observations were made here last spring with the object of determining the present rate of rotation of the great equatorial current of *Jupiter*. Valuable observations were also received from the undermentioned observers, and have been of great assistance in this research—namely, Messrs. E. M. Antoniadi, Juvisy; L. Brenner, Lussinpiccolo; H. F. Griffiths, Streatham; H. MacEwen, Glasgow; W. H. Maw, South Kensington; T. E. R. Phillips, Yeovil. So that, although the weather proved exceptionally unfavourable, eight spots situated on the north side of the south equatorial belt were observed sufficiently well to enable good determinations of the rotation period to be derived. The observations of these spots are given further on.

In all work of this kind it is of the utmost importance that there should be no possibility of doubt concerning the identity of the markings observed. It is very desirable, therefore, that observers, when stating the results of their investigations, should publish also the observations upon which these results are based; and this is even more important when such results differ materially from those of earlier investigators. In the present instance I have been careful not to include any doubtful cases, and the observations are so numerous, so distributed, and so accordant, that it seems impossible that there can be any doubt as to identity. Most of the columns in the following tables explain themselves. The third column gives the weight attributed to the observation at the time on a scale ranging from 1 (bad) to 5 (good).* The rotation periods have been computed from certain selected observations, and these weights are useful in selecting the best observations, but they have not been made use of in any other way in the calculations. The residuals in the fifth column will show how far the observations are satisfied by the adopted period of rotation in the case of each spot. The longitudes in column 4 are according to "System 1" of the late Mr. Marth's Ephemeris. The last column contains the initials of the observer.†

* For the meaning of "est." = estimated transit in connection with an observation by Mr. MacEwen, see *Journal B.A.A.* vol. vii. p. 271; and in connection with an observation by the writer, see *Monthly Notices*, vol. liv. p. 298.

† Most of the transits of equatorial spots by Mr. Gledhill, published in the Supplementary Number of the *Monthly Notices*, refer to spots on the N. equatorial belt. An observation of the dark spot *b* on May 9 has, however, been added in its proper place. A small *bright* spot on the N. edge of his belt 3 is stated to have been on the central meridian, at $8^h\ 27^m$, on April 28. This would give a position close to the *dark* spot *c*, so that belt 3 is probably a misprint for 5.

White Spot a.

Date	G.M.T. of Transit.	Wt.	Longitude.	O–C.	Observer.
1897	h m		°	m	
Feb. 18	9 40·9	...	39·0	+ 3·7	L. B.
25	8 54·8	...	37·1	– 1·5	„
Mar. 6	9 27	3	38·8	– 1·4	A. S. W.
8	10 40·3	3	39·6	– 0·8	„
10	11 57·7	2	42·9	+ 4·0	„
19	12 27·1	2	42·4	+ 0·5	„
Apr. 3	6 44·6	...	42·6	– 3·8	L. B.
9	10 40	est.	(53·5)	(+12·1)	H. M.
25	10 24	2	49·3	+ 0·3	A. S. W.
30	8 38·6	...	54·1	+ 6·7	L. B.
May 9	9 4·4	...	50·0	– 2·9	„
9	9 4·5	2	50·0	– 2·8	A. S. W.

Dark Spot b.

Date	G.M.T. of Transit.	Wt.	Longitude.	O–C.	Observer.
Feb. 11	10 44	4	(51·1)	(+ 6·5)	H. M.
27	10 35·9	...	(54·7)	(+ 6·8)	T. E. R. P.
Mar. 6	9 53	3	(54·7)	(+ 4·2)	A. S. W.
8	11 0·8	4	52·1	– 0·8	„
10	12 14·7	3	53·3	+ 0·5	„
Apr. 25	10 47	est.	63·3	+ 0·7	„
30	8 55	3	64·1	+ 0·3	„
May 9	9 30	2	65·6	– 0·5	„
9	9 19	...	(58·9)	(–11·5)	J. G.

Dark Spot c.

Date	G.M.T. of Transit.	Wt.	Longitude.	O–C.	Observer.
Feb. 23	9 13	est.	92·1	+ 1·5	A. S. W.
Mar. 1	12 45·9	...	90·0	– 2·1	T. E. R. P.
6	10 54	3	91·9	+ 0·7	A. S. W.
8	12 4·3	3	90·8	– 1·2	„
Apr. 7	10 34·7	est.	94·4	+ 3·6	„
14	9 47	1	90·5	– 3·2	„
30	9 42	2	92·8	– 0·1	„
May 14	8 23	3	93·6	+ 0·7	„

White Spot d.

Date	G.M.T. of Transit.	Wt.	Longitude.	O—C.	Observer.
1897	h m		°	m	
Jan. 17	11 52	1	101·8	+ 3·1	H. M.
Feb. 23	9 29	3	101·9	– 1·6	A. S. W.
Mar. 6	11 14	2	104·1	+ 0·6	„
8	12 25·3	1	103·6	– 0·5	„
Apr. 7	10 55·7	2	107·2	+ 1·6	„
14	10 10	2	104·5	– 3·8	„
30	9 57·4 (?)	...	(102·2)	(– 9·7)	L. B.
May 14	8 49	1	109·4	+ 0·4	A. S. W.
			Dark Spot e.		
Jan. 17	12 0	2	106·7	– 0·1	H. M.
Apr. 28	9 21·2 ±	...	124·4	+ 3·2	A. S. W.
May 5	8 38·7	est.	123·2	– 0·6	„
14	9 15	2	125·3	+ 0·7	„
			White Spot f.		
Apr. 10	10 48·5	2	216·5	– 3·4	A. S. W.
24	9 36	2	222·2	+ 3·9	„
May 3	10 4·8	est.	220·1	– 0·9	„
June 25	8 3·3	...	225·7	+ 0·6	L. B.
			Dark Spot g.		
Feb. 3	(13 8)	2	(314·6)	(– 7·3)	H. M.
Mar. 19	10 15·1	2	321·9	– 1·2	A. S. W.
Apr. 27	9 18·2	2	324·9	– 1·5	„
May 4	8 43·3	est.	328·2	+ 3·0	„
6	9 55·8	est.	328·0	+ 2·4	„
13	9 12·5	1	326·0	– 1·8	„
20	8 34·5	2	327·2	– 0·8	„
			Dark Spot h.		
Feb. 3	14 0	est.	346·3	– 1·1	H. M.
Apr. 25	8 49	3	351·5	– 3·1	A. S. W.
27	10 11·2	1	357·2	+ 6·0	„
May 4	9 23·3	2	352·6	– 2·4	„
13	9 57·5	1	353·5	– 2·1	„
15	11 15·5	1	356·5	+ 2·6	„

Notes.

Spot b. The rot. per. depends upon the observations from Mar. 8 to May 9. On Mar. 6 the spot appeared as a close double spot, a smaller companion lying just following. The time given is that of this double spot considered as

one mass. The observations of Feb. 11 and 27 also evidently relate to the same phase. The later ones refer to the preceding component.

Spot g. This spot was on the north side of the S. Equat. Belt. The observation of Feb. 3 refers to a dark streak on the south edge of the same belt. It is doubtful, therefore, how far this observation relates to Spot *g*, if it does so at all.

Spot h. On April 27 the spot was double and observed as one mass. The last observation was made with a $2\frac{3}{4}$-inch refractor. The transits observed by Mr. Phillips being uniformly earlier than those by the writer, the times given here are the observed times + $5^{m}\cdot9$, the average amount of the difference (from four comparisons).

The following are the adopted periods of rotation, together with the number of rotations elapsed between the first and last observations on which each period is based.

Spot.	Per. of Rotation.	No. of Rotations.	Spot.	Per. of Rotation.	No. of Rotations.
	h m s			h m s	
a	9 50 37·6	156	*e*	9 50 36·3	285
b	38·7	151	*f*	33·6	185
c	31·0	195	*g*	33·3	151
d	33·2	285	*h*	33·2	241

Mean = $9^{h}\ 50^{m}\ 34^{s}\cdot6$ (8 spots).

The mean period of rotation of the equatorial current in 1897 was therefore $9^{h}\ 50^{m}\ 34^{s}\cdot6$. This relates to the southernmost portion of the current, to which nearly all previous determinations also refer. The above eight spots were all situated on the north side of the south equatorial belt.*

II. *On the Change in the Rate of Rotation of the Equatorial Current.*

One of the most remarkable facts known in connection with the physical condition of the planet *Jupiter* is the continual decrease in the velocity of the equatorial current since 1879. A list of the different determinations of the period of rotation of this current will be found in the *Monthly Notices*, vol. lvi. p. 147. In order to reduce these into a more manageable form, each result has been given an arbitrary weight. Generally, each determination of the rotation period of a spot has been given weight 1, but a less weight has been assigned wherever the interval of time covered by the observations is short, or there are any other circumstances which might affect the accuracy of the result. The average values for each opposition have then been

* Two prominent dark spots on the south edge of the north equatorial belt give the following results:

Dark spot *i* R = $9^{h}\ 50^{m}\ 32^{s}\cdot3$ (217 rotations).

" " *k*.R = $9^{h}\ 50^{m}\ 39^{s}\cdot7$ (156 ").

found from these weighted results,* and are given in the following table :—

Opposition.	Mean Per. of Rot.	Weight.	C–O.
	h m s		s
1879	9 49 59	1	0·0
1880	9 50 5·0	7	–1·8
1881	10·2	2	–3·2
1882	9·7	2	+1·0
1884	12·4	2	+1·7
1885	14·3	1	+2·9
1886	22·9	1	–2·8
1887	22·4	21	+0·3
1888	31·4	3	–6·3
1891	26·4	1	+4·2
1897	34·6	8	–0·1

The above table shows clearly the remarkable and continual increase in the period of rotation since 1879, a period of eighteen years. The total increase in the period of rotation since 1879 is $35^{s}{\cdot}6$, and this is equivalent to a decrease of 26 miles (42 kilometres) per hour in the actual velocity of the current. The decrease in velocity, however, clearly takes place at a slower rate now than formerly, as is evident from the preceding table, which shows also that there has been a progressive decrease in the rate of change. The observed changes in the length of the period of the equatorial current are represented well enough by the formula $R = 9^{h}\ 49^{m}\ 59^{s} + t \times (4^{s}{\cdot}3 - 0^{s}{\cdot}13t)$, where R is the period of rotation and t the interval of time expressed in oppositions of *Jupiter* elapsed since 1879. The residuals C—O have been added in the last column of the foregoing table in order to show how far the observed values are represented by this formula. The increase in the length of the rotation period has apparently now nearly come to an end, and after next year should be succeeded by a decrease, which would mean of course an increase in the actual velocity of the current, though the change at first would be small. It is very desirable, therefore, that the rate of rotation should be re-determined in the next and succeeding apparitions of *Jupiter*. And the importance of basing such determinations on the observations of a number of spots cannot be too strongly insisted upon.

1897 October 18.

* The effect of this mode of combination is to give a relatively high weight to a result based upon a large number of spots.

On the Nature of the Orbit of γ Lupi. By T. J. J. See, A.M., Ph.D. (Berlin).

The brilliant southern binary γ *Lupi* was discovered by Sir John Herschel, at the Cape of Good Hope, 1834 June 9. The measures secured by him during the next four years define the place of the companion at that epoch with considerable precision; and, as might have been predicted from the appearance of this striking system, time has shown that it is in orbital motion. After Herschel's return to England a long period elapsed before it was again resolved by any telescope in the southern hemisphere, though it was frequently examined with instruments at least equal to that employed in the earliest work at the Cape.

Mr. Russell, of Sydney, deserves our special thanks for the records secured by him from 1874 to the present time with his 11½-inch telescope, which under good conditions ought to separate a nearly equal pair like γ *Lupi* at a distance of 0″·4. For, although these records are of a negative character, they possess the highest interest. The fact that Mr. Russell and his assistants examined this object on many occasions prior to 1880, without being able to divide it, long ago made known that it had narrowed up after the time of Herschel. As the Sydney observers are still unable to divide it, the observations recently secured by Mr. Cogshall and the writer with the Lowell 24-inch refractor at Mexico are the first actual measures of the system for sixty years. These data define the present position of the companion with a high degree of precision, and throw an interesting light upon the character of the orbit; and hence I submit herewith the conclusions at which we have arrived. We swept over the star (unaware that it was γ *Lupi*) on the morning of 1897 January 17, and I saw at once that it was double, and indeed divided clearly, though by no means a very easy object even with the great telescope. It was subsequently re-examined on several nights, and no difficulty was experienced in securing good measures; yet when the seeing was deteriorated it became difficult to measure, and thus during our later work this well-known object served as a most trustworthy and convenient index to the state of the atmosphere. Here at Flagstaff, notwithstanding the low altitude of only 14°, the fine seeing afforded by our location has enabled me to divide it on several occasions during the past summer. The following are all the observations to the present time:—

Complete Observations of γ Lupi.

t	θ	ρ	n	Observers.	Remarks.
1834·504	98°·5	0·72	3	Herschel	Refractor.
1835·335	94·8	0·85	6–2	„	„
1836·282	93·0	1·00	2–1	„	„
1836·523	95·5	0·67	1	„	Reflector
1837·265	94·8	0·67	4–2	„	Refractor
1871·465	Well defined but not divided.		...	Russell	7½-inch refractor.
1877·502	270° ± smaller end goes first.		...	„	11½-inch; powers 480, 800, 1,200.
1880·578	270 ± elongated.		...	„	
1881·548	Round, with powers to 800.		...	„	
1886·570	Uncertain elong. in 90°.		...	„	Definition not good.
1886·570	Round, with all powers on 7½-inch telescope.		...	Pollock	
1887·531	Single. with 800 on 11½-inch.		...	„	Never saw better definition; γ *Lupi* is not like ζ *Sagittarii* measured on the same night. Dist. 0″·6.
1895·56	Single, good definition.		3	Sellors	
1897·065	92°·4	0″·34	2	See	Nicely separated.
1897·086	90·4	0·47	1	Cogshall	Divided.

Our measures indicate that the present distance is slightly less than 0″·4, and hence we may easily understand Mr. Russell's inability to divide it. He writes in a letter of August 30: "We have regularly looked at it, and always without dividing it. The last time it was in a favourable position, Mr. Sellors examined it several times, and could see no sign of division." Herschel's measures show that it was not very difficult in his time. Taking all the evidence into consideration, we may fix the place as substantially this:

1835·0 94° 0″·8

The distance at that epoch could hardly be less than 0″·8, for Herschel remarks: "Clearly divided with power of 480, and black division well seen; well separated with 800." And in speaking of π *Lupi* he says: "Excessively difficult. It is closer than γ *Lupi*, for the discs are smaller, and yet are not so much divided." "I do not think better measures of this star will be got

with this instrument." Herschel made the distance of *π Lupi* 0″·67 (on other occasions about 0″·80); and as this object is known by more recent measures to be steadily widening out, we may accept his distance of *π Lupi* as quite trustworthy. For taking the present distance (1″·30) of *π Lupi*, and going back in time, we find that in 1835 it must have been separated by at least 0″·75. Assuming, therefore, that *γ Lupi* was separated by 0″·8 in 1835, we may summarise the case as follows :—

1. The present position in 92°, 0″·34 shows that the plane of the orbit passes nearly through the Sun, and that the companion thus oscillates in a right line like that of 42 *Comæ Berenicis* (*Monthly Notices*, 1896 November).

2. Assuming that the distance was 0″ 8 in 1835, as indicated by the work of Herschel, the present distance, 0″·34, shows that in 1877 it ought to have been easily separated with an 11½-inch telescope had the companion merely narrowed up at about a constant rate without yet occulting the large star; for on this hypothesis the distance would then have been 0″·50. Mr. Russell made it on the opposite side, in 270° ±, and presumably at a distance of about 0″·35. In describing the image he expressly notes that the "smaller end goes first"

3. In view of Mr. Russell's inability to divide the object in 1877, we may infer that the distance had certainly become less than 0″·4, and that the companion had widened out to about this distance on the other side. It is thus clear that the companion has passed periastron, and is now again approaching the position where Herschel saw it in 1835.

4. We thus have satisfactory evidence that *γ Lupi* has already made a large part of a revolution, and that the situation of the orbit is similar to that of 42 *Comæ Berenicis*, which heretofore has been unique among all known stellar systems.

5. The period cannot yet be fixed with any precision, for we are unable to ascertain the distance to which the companion recedes in angle 93°. If the distance in the time of Herschel was about a maximum (which is not improbable) the period could be confined within a century.

It thus appears that the system of *γ Lupi* is in every way one of surpassing interest, and will deserve the constant attention of southern observers. If careful measures can be secured for the next twenty years, an approximate determination of the orbit will then be possible. The system has a very small proper motion, according to Auwers:

$$\text{in } \alpha = -0^{s}\!\cdot\!0054$$
$$\text{in } \delta = -0''\!\cdot\!037$$

Accordingly, there is a probability that this extraordinary binary is very remote and of large dimensions. If this conjecture be true, the brilliancy of the stars composing it shows that they are enormously luminous and probably of great mass.

The place for 1900·0 is

$$\alpha = 15^h\ 28^m\ 28^s{\cdot}4$$
$$\delta = 40^\circ\ 49'\ 50''{\cdot}2$$

While the present results indicate the general character of the motion, it is obvious that the work of many years will be required to define the orbit with great accuracy; yet I have thought proper at this time to direct attention to the first fruit of what must be considered to be one of the most fortunate of Herschel's discoveries made more than sixty years ago.

Lowell Observatory, Flagstaff, Arizona:
1897 *October* 1.

List No. 4 for 1900·0 *of Nebulæ discovered at the Lowe Observatory, California.* By Lewis Swift.

No.	Date. 1897.	R.A. h m s	Dec. ° ′ ″	Descriptions.
1	Sept. 23	0 11 0	−39 52 20	eeeF, vL, eE, close f 55, f of 2. Note.
2	Oct. 3	0 54 30	−34 51 32	pB, vS, R, 2 st nf, and 2 np.
3	Sept. 29	1 5 0	−46 31 38	vF, S, R, no B ✱ near, vF one f.
4	29	1 53 4	−33 31 27	pB, vS, R, BM 10ᵐ ✱ v close sp.
5	29	2 5 0	−33 25 0	vF, vS, eE, nearly 0°, F ✱ p.
6	29	2 59 28	−39 52 38	eF, pS, R, FD ✱ sf point to it.
7	26	3 31 0	−34 46 55	pB, S, eeeE, a straight hair-like line 90°. Note.
8	29	4 8 45	−33 7 51	eF, vS, R, BM, 10ᵐ ✱ close s.
9	29	4 16 30	−31 41 42	eeF, pL, R.
10	Aug. 10	19 53 30	−38 47 38	vF, S, R, 8ᵐ ✱ f, 90°, p of 2, same parallel.
11	10	19 54 0	−38 47 38	vF, S, R, 8ᵐ ✱ f, f of 2.
12	July 8	20 0 0	−48 35 50	B, cE, vS, stellar, f of 2.
13	Sept. 23	20 10 59	−41 53 24	vF, cS, R, no B ✱ near.
14	16	20 24 25	−36 39 15	vF, cS, R, several pB st sf.
15	17	20 40 25	−38 50 35	eeF, pS, R.
16	15	21 1 31	−30 26 30	eeF, pS, R, F ✱ near f, 90°.
17	17	21 41 0	−35 21 58	vF, vS, R.
18	17	21 42 0	−35 27 0	vF, pL, R. Not 7130 or 7135; sp of 2.
19	17	21 43 30	−35 22 10	eeF, pL, R, 3 B st p = Δ nf of 2.
20	27	21 49 46	−49 31 52	eeF, pS, R, in line with 2·9ᵐ st sf, 7ᵐ ✱ in field sf.
21	23	22 51 30	−43 59 27	pB, S, R, mbM.
22	Oct. 3	23 27 45	−45 35 40	vF, S, R, bet 2 st, 8ᵐ ✱ sf and 7ᵐ ✱ sp.
23	Sept. 23	23 39 25	−43 29 15	eF, eS, R, stellar.
24	25	23 42 40	−37 36 53	eeF, CS, R, in vacancy.
25	25	23 52 25	−37 34 52	pB, CS, eE, 1 star near sf.

Notes.

This list, the fourth issued from this observatory, bringing the total to 130, contains, as will be seen, only southern nebulæ. They are, with a few exceptions, very faint, though some are bright enough to come under Herschel's Class I., and the fact of their not having been previously found shows that the southern sky has not been so thoroughly searched over for nebulæ as the northern, and that portion of the southern within the reach of Sir William Herschel and Lord Rosse.

Note to No. 1 = G.C., 27 = N.G.C. 55, is with its associated companion a remarkable nebula. I am at a loss what to think of it, whether it is all one nebula, the preceding half vv bright, v large, exceedingly elongated, the following half ee faint, equally large, and still more elongated, or if there are not two nebulæ, one partly overlapping the other. If single, it is curved; if double, the components are inclined to each other. I am inclined to think there are two distinct nebulæ, one reason being that the brighter one ends sharply, which would hardly be the case if the brighter merged into the fainter. The brighter was discovered by Dunlop, but I doubt if he could have seen the fainter. The fact that Sir John Herschel does not mark it with a sign meaning a very remarkable or even a remarkable object—as he often has done—lends plausibility to the supposition that the fainter portion was not seen by him. As, however, it has been illustrated, a reference to the illustration would settle the matter at once.

No. 7. This in one respect is the most remarkable nebula I have ever seen. I doubt if the entire heavens afford a similar example. If the reader will cut off a short piece of fine bright brass wire and hold it up sidewise to the sky he will form by looking at it a very correct idea how it appeared to me. The line was certainly nebulous. It must be a thin nebulous disc seen exactly edgewise.

G. C. 383 does not exist, and must be struck out. Sir John Herschel makes 380 and 383 of equal brightness, and the places given would place both well within my field of 31′ in diameter, power 132. I made a long and thorough search for 383, and should have found it if there, had it been three times fainter than 380, which is an easy object.

Occultation of the Pleiades, 1897 *July* 23.
By W. E. Plummer, M.A.

The following observations were made at Bidston Observatory, under decidedly unfavourable meteorological conditions. The sky was repeatedly covered with cloud, and a haze was at all times present which rendered some of the stars very faint when near the limb of the Moon, and also interfered with definition. No apparent projection of the stars on the Moon's disc was noticeable at either disappearance or re-appearance. The nomenclature is that of Bessel.

Star.	Phenomenon.	Observed Local Time.			Star.	Phenomenon.	Observed Local Time.		
		h	m	s			h	m	s
Electra	Disappearance	12	9	25·3	Alcyone	Disappearance	13	13	19·9
8	"	12	44	14·5	Merope	Re-appearance	13	27	29·3
Merope	"	12	44	53·0	9	"	13	39	33·3
4*	"	12	53	45·8	29	Disappearance	13	46	15·1
13	"	12	58	49·0	Pleione	"	14	4	52·8
15	"	13	2	0·5	Alcyone	Re-appearance	14	7	29·5
18	"	13	8	38·1	32	Disappearance	14	9	30·7
p	"	13	9	23·5					

Liverpool Observatory:
1897 *November* 11.

* In the case of this star some doubt was entertained whether the star was really occulted or simply obscured by cloud at the time of closest approach. The path of the Moon seemed to indicate that it would be hidden, but suspicion was raised when seen later.

Equatorial Comparisons of Uranus with 41 Libræ, and a Probable Occultation of the Star by the Planet. By John Tebbutt.

On 1897 September 5 I commenced a series of comparisons of *Uranus* and 41 *Libræ* by means of the 8-inch equatorial and filar micrometer. On completing the first three nights' observations it appeared to me that the planet would, on the evening of September 8, either occult the star or approach extremely close to it. As absence from home would prevent my observation of this interesting appulse, I requested two prominent Members of the local branch of the British Astronomical Association to watch for the phenomenon. I have since heard from Mr. C. J. Merfield that he saw the planet within $5''$ of the star at $7^h\ 20^m$, and concluded that it had been much closer at sunset. He afterwards found from the theoretical places in the *Nautical Almanac* that the star must have suffered occultation shortly before sunset, and the observed coordinates communicated in this paper will confirm this conclusion. The accompanying observations have been made under fairly good conditions, and many of them during twilight. The centre of the planet's disc was the point observed throughout.

The star's mean place for 1897·0 has been derived from the following catalogues:—Greenwich, 1840, 1850, 1880; Cape, 1850, 1885; Argelander-Oeltzen, 1850; Radcliffe, 1860, 1890; Washington, 1860, 3rd ed.; Brussels, 1865; Cordoba, 1875; and Melbourne, 1880. The reductions for mean place have been made by means of the annual precessions and secular variations of the Greenwich Catalogue, 1880, checked by those of the Radcliffe Catalogue, 1890, and the proper motion has been taken from the same two authorities. The resulting mean place, assigning equal weights to the authorities, is R.A. $= 15^h\ 32^m\ 58^s{\cdot}70$, N.P.D. $= 108^\circ\ 57'\ 45''{\cdot}1$ The observations have been compared with the transit ephemeris on p. 279 of the *Nautical Almanac*, and the means of the resulting corrections, namely $-0^s{\cdot}35$, $-0''{\cdot}8$, agree closely with $-0^s{\cdot}32$, $-1''{\cdot}2$, the results derived by me from comparisons with α *Libræ* on 1894 October 5. See *R.A.S. Monthly Notices*, vol. lv. p. 83. In concluding this paper I would suggest the desirability of improving the Table of Phenomena in the *Nautical Almanac* by the more free insertion of conjunctions of planets with well-known stars, for results derived from micrometric measures at such opportunities are, I think, quite equal to those from ordinary meridian observations. I may add that *Neptune* will pass within micrometric distance of 114 *Tauri* at his opposition in December next.

Results of Micrometer Comparisons of Uranus and 41 Libræ.

1897.	Windsor Mean Time.	Comps.	Planet's Centre − Star. R.A.	Planet's Centre − Star. N.P.D.	Star Reductions. R.A.	Star Reductions. N.P.D.	Parallax Corrections. R.A.	Parallax Corrections. N.P.D.	Geocentric Apparent Place of Planet's Centre. R.A.	Geocentric Apparent Place of Planet's Centre. N.P.D.	Corrections to *Nautical Almanac.* R.A.	Corrections to *Nautical Almanac.* N.P.D.
	h m		s	′ ″	s	″	s	″	h m s	° ′ ″	s	″
Sept. 5	7 9 31	30	−21·10	−1 18·6	+2·84	+14·6	+0·02	+0·2	15 32 40·46	108 56 41·3	−0·30	−1·5
6	6 48 38	30	−14·18	−0 52·5	+2·83	+14·6	+0·02	+0·1	15 32 47·37	108 57 7·3	−0·29	−0·8
7	7 47 6	30	− 6·68	−0 25·5	+2·81	+14·5	+0·02	+0·2	15 32 54·85	108 57 34·3	−0·31	−1·2
9	7 18 29	30	+ 8·14	+0 29·0	+2·79	+14·5	+0·02	+0·2	15 33 9·65	108 58 28·8	−0·34	−0·5
10	6 32 9	30	+15·66	+0 56·2	+2·77	+14·4	+0·02	+0·1	15 33 17·15	108 58 55·8	−0·36	−0·8
11	7 7 10	30	+23·83	+1 26·0	+2·76	+14·4	+0·02	+0·2	15 33 25·31	108 59 25·7	−0·35	−0·3
12	6 49 27	13	+31·75	+1 55·1	+2·74	+14·3	+0·02	+0·2	15 33 33·21	108 59 54·7	−0·49	−0·3
13	7 36 57	20	+40·47	+2 25·8	+2·73	+14·3	+0·02	+0·2	15 33 41·92	109 0 25·4	−0·37	−0·6

Windsor, N.S. Wales:
1897 *September* 25.

Observations of Comet b 1897 (Perrine) made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

1897.	Greenwich Mean Solar Time.	Observer.	☄−✱ R.A.	Corr. for Refraction.	Log. Factor of Parallax.	☄−✱ N.P.D.	Corr. for Refraction.	Log. Factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
	d h m s		m s	s		′ ″	″			h m s	° ′ ″	
Oct.	21 10 42 19	C. D.	−4 11·35	+0·04	9·8596n	−6 18·7	+0·2	0·4014	4	2 57 32·84	16 5 7·3	*a*
	21 10 44 46	„	−3 25·57	−0·04	9·8522n	+5 19·6	−0·1	0·4063	3	2 57 30·88	16 4 55·5	*b*
	24 8 0 2	W.	+0 57·49	+0·01	0·1755n	−0 36·0	0·0	0·1033	6	2 11 36·45	12 12 17·9	*c*
	24 8 0 2	„	+0 48·00	+0·09	0·1755n	−4 29·9	+0·1	0·1033	6	2 11 34·17	12 12 18·6	*d*
	25 7 6 30	C. D.	+0 31·90	+0·08	0·2381n	−3 36·6	+0·1	9·9157	9	1 49 27·96	11 5 24·6	*e*
	26 8 59 23	A. C.	+1 18·96	+0·03	0·0191n	−1 49·6	+0·1	0·5478	3	1 19 32·20	10 0 39·2	*f*
	30 6 40 38	C. D.	+0 6·19	−0·06	9·9871n	+3 37·1	−0·2	0·6064	6	22 48 24·51	8 19 10·7	*g*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

Oct. 21.—The Comet was bright.
Oct. 24.—The Comet was fairly bright, with faint nucleus and a short tail.
Oct. 26.—The night was hazy and the Comet faint and ill-defined.
Oct. 30.—The Comet appeared much fainter.

The initials A. C., C. D., and W. are those of Mr. Crommelin, Mr. Davidson, and Mr. Witchell respectively.

Comparison Stars.

	Star's Name	Assumed R.A. 1897·0.	Assumed N.P.D. 1897·0	Authority.
		h m s	° ′ ″	
a	Groombridge 604	3 1 33·74	16 11 42·0	Greenwich Ten-Year Catalogue, 1890 (Manuscript).
b	Bradley 417	3 0 46·01	15 59 52·3	,, ,, ,, ,,
c	Groombridge 469	2 10 27·32	12 13 16·8	,, ,, ,, ,,
d	Oeltz. Arg. (N) 2523	2 10 34·50	12 17 11·3	Oeltzen-Argelander (North).
e	BD + 78° No. 63	1 48 44·25	11 9 26·6	Bonn Observations, vol. vi.
f	Anonymous	1 18 1·85	10 2 57·4	Greenwich Observations, 1897.
g	Carrington 3503	22 48 15·50	8 16 10·3	Carrington's Red Hill Catalogue.

Royal Observatory, Greenwich:
1897 *November* 12.

Approximate Ephemeris of the Leonids, from 1897 *December* 24 *to* 1898 *April* 8.

(*Communicated by G. Johnstone Stoney, D.Sc., F.R.S.*)

The following ephemeris of the part of the swarm of the *Leonids* which passed close to the Earth in 1866 is a continuation of the ephemeris in the *Monthly Notices* for 1896 December, and is intended to prepare for another attempt to photograph the meteors in the open sky. There was no perceptible impression on the photographic plate in the trial made by Dr. Isaac Roberts last spring; but it has been thought desirable to repeat the observation, since the conditions will be somewhat more favourable in the coming season, owing to the increasing intensity of sunshine upon the meteors, which will make the brightness of the image of the stream upon the photographic plate about three times what it was last season.

It was from the first recognised that it falls short of being probable that even a great depth of bodies so small and so scattered will sufficiently impress the most delicate photographic plates we possess. But inasmuch as what is aimed at is not actually impossible, and as the gain to astronomy will be great if it is attained, it has been thought desirable to make preparation for another attack.

The ephemeris has been drawn up under the kind direction of Dr. Downing, Superintendent of the Nautical Almanac, and the computations have been made by Mr. Thomas Wright, of the National Almanac Office. The cost has been defrayed out of a grant made by the Royal Society.

Greenwich, midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.	Greenwich, midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.
1897.	h m s	° ′		1898.	h m s	° ′	
Dec. 24	14 10 54	S. 5 29	0·8995	Jan. 7	14 12 59	S. 5 21	0·8817
25	14 11 6	5 29	0·8983	8	14 13 5	5 20	0·8803
26	14 11 17	5 28	0·8970	9	14 13 10	5 19	0·8790
27	14 11 28	5 28	0·8958	10	14 13 15	5 18	0·8776
28	14 11 38	5 27	0·8946	11	14 13 19	5 17	0·8762
29	14 11 48	5 27	0·8933	12	14 13 23	5 15	0·8749
30	14 11 58	5 27	0·8921	13	14 13 26	5 14	0·8735
31	14 12 7	5 26	0·8908	14	14 13 29	5 13	0·8721
1898.				15	14 13 31	5 12	0·8707
Jan. 1	14 12 16	5 25	0·8895	16	14 13 33	5 10	0·8693
2	14 12 25	5 25	0·8882	17	14 13 34	5 9	0·8679
3	14 12 33	5 24	0·8869	18	14 13 35	5 7	0·8664
4	14 12 40	5 23	0·8856	19	14 13 35	5 5	0·8650
5	14 12 47	5 23	0·8843	20	14 13 34	5 4	0·8635
6	14 12 53	5 22	0·8830	21	14 13 33	5 2	0·8621

Greenwich, midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.	Greenwich, midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.
1898.	h m s	° ′		1898.	h m s	° ′	
Jan. 22	14 13 32	S. 5 0	0·8607	Mar. 2	14 4 41	S. 3 3	0·8042
23	14 13 30	4 58	0·8593	3	14 4 14	2 59	0·8029
24	14 13 28	4 57	0·8578	4	14 3 47	2 55	0·8016
25	14 13 25	4 55	0·8564	5	14 3 19	2 50	0·8003
26	14 13 21	4 53	0·8549	6	14 2 50	2 46	0·7990
27	14 13 17	4 50	0·8535	7	14 2 21	2 42	0·7977
28	14 13 12	4 48	0·8520	8	14 1 52	2 37	0·7964
29	14 13 6	4 46	0·8505	9	14 1 22	2 33	0·7951
30	14 13 0	4 44	0·8490	10	14 0 51	2 28	0·7939
31	14 12 54	4 41	0·8476	11	14 0 20	2 24	0·7926
Feb. 1	14 12 47	4 39	0·8461	12	13 59 48	2 19	0·7914
2	14 12 39	4 37	0·8446	13	13 59 16	2 15	0·7902
3	14 12 30	4 34	0·8431	14	13 58 43	2 10	0·7890
4	14 12 21	4 31	0·8417	15	13 58 9	2 5	0·7879
5	14 12 11	4 29	0·8402	16	13 57 35	2 1	0·7867
6	14 12 1	4 26	0·8387	17	13 57 0	1 56	0·7856
7	14 11 50	4 23	0·8372	18	13 56 24	1 51	0·7845
8	14 11 38	4 21	0·8357	19	13 55 48	1 46	0·7834
9	14 11 26	4 18	0·8342	20	13 55 13	1 41	0·7823
10	14 11 13	4 15	0·8328	21	13 54 37	1 36	0·7813
11	14 11 0	4 12	0·8313	22	13 54 0	1 32	0·7802
12	14 10 47	4 9	0·8298	23	13 53 22	1 27	0·7792
13	14 10 32	4 6	0·8284	24	13 52 43	1 22	0·7782
14	14 10 16	4 2	0·8269	25	13 52 5	1 17	0·7773
15	14 10 0	3 59	0·8254	26	13 51 26	1 12	0·7763
16	14 9 43	3 56	0·8240	27	13 50 47	1 7	0·7754
17	14 9 26	3 52	0·8225	28	13 50 7	1 1	0·7745
18	14 9 8	3 49	0·8211	29	13 49 26	0 56	0·7736
19	14 8 49	3 45	0·8196	30	13 48 45	0 51	0·7727
20	14 8 30	3 42	0·8182	31	13 48 4	0 46	0·7719
21	14 8 10	3 38	0·8167	Apr. 1	13 47 23	0 41	0·7711
22	14 7 49	3 35	0·8153	2	13 46 41	0 36	0·7703
23	14 7 28	3 31	0·8139	3	13 45 59	0 31	0·7695
24	14 7 6	3 27	0·8125	4	13 45 17	0 26	0·7688
25	14 6 43	3 23	0·8111	5	13 44 34	0 21	0·7681
26	14 6 20	3 19	0·8097	6	13 43 51	0 16	0·7674
27	14 5 56	3 15	0·8083	7	13 43 8	0 10	0·7667
28	14 5 31	3 11	0·8070	8	13 42 25	0 5	0·7661
Mar. 1	14 5 6	3 7	0·8056				

A Spectroscopic Method for Determining the Second and Third Contacts during a Total Eclipse of the Sun. By William Shackleton, A.R.C.Sc.

The spectroscopic method by which the determination of all the contacts can be made, as given by Faye and Young in 1869, although capable of giving very accurate results, requires at the same time a moderately powerful spectroscope attached to a telescope, and also a great nicety of adjustment.

For many purposes at the actual time of eclipse the second and third contacts are more important than the others, so for the benefit of eclipse observers I give the following method by which these can be determined, being the one I employed during the total eclipse of 1896 August 9 in Novaya Zemlya, requiring no larger size of instrument than can be put into one's waistcoat pocket.

If at any time the Sun be looked at through a prism, a band of continuous spectrum will be seen, but in a total eclipse of the Sun, as the Moon advances, the Sun's disc will be gradually obscured until there is only a thin crescent left; if now this crescent be examined by means of the prism with the refracting edge parallel to the line joining the horns of the crescent, it will be seen that a slit is unnecessary, for eventually the remaining portion of the Sun's photosphere becomes so thin that the Fraunhofer groups make their appearance as curved lines. (This can be seen at any time by looking at the Moon with the same apparatus when a very thin crescent.)

A very convenient form of instrument to use is a small direct vision prism; the one I employed was an ordinary Maclean eyepiece or star spectroscope (kindly lent me by General A. de Gorloff), with the cylindrical lens removed. With such a small instrument the whole of the rapidly thinning crescent can be observed at once, and at length the continuous band of spectrum begins to get narrower, and bright arcs representing the spectrum of the chromosphere, corresponding in position to H_α, D_3, H_β, and H_γ, appear protruding at either side. It is now necessary to be on the alert, for these bright arcs grow rapidly in brightness and length, while the continuous band which they can be seen to cross grows correspondingly narrower with the waning photosphere, until at last with great rapidity it thins out to nothing, which moment of disappearance marks the time of second contact.

For the determination of the third contact it is necessary to observe the reverse phenomenon, *i.e.* the appearance of the continuous spectrum, crossing at right angles and in the middle of

their lengths the long chromospheric arcs seen near the end of totality; this point of re-appearance gives the time of third contact. Immediately preceding this, however, and in the same position, a great many short arcs parallel to the long chromospheric ones will flash in momentarily; these represent the spectrum of the reversing layer, and may be used as a warning that the photosphere will reappear within a few seconds after.

That this method is really capable of giving a fairly accurate result can be gathered from the "Preliminary Report on the

Ephemeris for Physical Observations of Jupiter,

Greenwich Noon	P	L−O	B	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d	u	B′
1897.	°	°	°	″	″	″	°	°	°
Dec. 10	25·114	51·782	−2·332	35·28	0·26	33·07	9·87	268·44	−2·49
12	25·096	52·029	2·348	35·47	·27	33·25	9·97	268·40	2·50
14	25·079	52·269	2·363	35·67	·27	33·43	10·06	268·36	2·52
16	25·062	52·499	2·378	35·86	·28	33·61	10·14	268·32	2·54
18	25·046	52·719	2·393	36·07	·28	33·81	10·20	268·28	2·55
20	25·030	52·930	2·408	36·28	·29	34·00	10·25	268·24	2·57
22	25·015	53·130	2·422	36·49	·29	34·20	10·30	268·20	2·58
24	25·000	53·320	2·436	36·70	·30	34·40	10·34	268·16	2·60
26	24·985	53·499	2·450	36·92	·30	34·60	10·37	268·12	2·61
28	24·971	53·668	2·464	37·13	0·30	34·81	10·38	268·08	2·63
30	24·958	53·825	2·477	37·36	0·31	35·02	10·39	268·05	2·64
1898.									
Jan. 1	24·945	53·971	2·490	37·58	·31	35·23	10·39	268·01	2·66
3	24·933	54·106	2·503	37·81	·31	35·44	10·38	267·97	2·67
5	24·922	54·229	2·516	38·04	·31	35·66	10·35	267·92	2·68
7	24·913	54·341	2·528	38·27	·31	35·87	10·31	267·88	2·70
9	24·904	54·440	2·540	38·51	·31	36·09	10·25	267·84	2·71
11	24·896	54·528	2·552	38·74	·31	36·32	10·19	267·79	2·72
13	24·889	54·603	2·564	38·97	0·30	36·54	10·12	267·74	2·73
15	24·883	54·666	2·575	39·21	·30	36·76	10·04	267·69	2·75
17	24·878	54·717	2·585	39·46	·30	36·98	9·92	267·63	2·76
19	24·875	54·755	2·595	39·70	·29	37·21	9·82	267·57	2·77
21	24·873	54·780	2·605	39·94	·29	37·44	9·69	267·51	2·78
23	24·872	54·793	2·614	40·18	·28	37·66	9·55	267·45	2·79
25	24·872	54·793	2·623	40·41	·27	37·88	9·40	267·38	2·80
27	24·872	54·780	2·632	40·65	·26	38·11	9·23	267·30	2·81
29	24·874	54·754	2·640	40·89	0·26	38·33	9·05	267·22	2·82
31	24·877	54·716	2·648	41·12	·25	38·55	8·86	267·14	2·82

Results obtained in Novaya Zemlya during the Eclipse of the Sun, 1896 August 9, with the Prismatic Camera." *

Note.—If all the contacts are to be determined, the first and fourth might be done by Young's method, and for estimating the second and third the same spectroscope could be employed with a very wide tangential slit at the points of disappearance and reappearance of the photosphere, or to give even a larger range of observation the slit might be removed altogether.

* *Phil. Trans.* vol. 189, p. 261. A. 1897.

1897–98. By A. C. D. Crommelin.

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time	A − O	*B*
1897	°	°	°	m	°	°
Dec. 10	147·53	139·91	+0·42	47·22	41·908	−2·055
12	103·23	80·35	·43	46·97	42·060	2·061
14	58·95	20·81	·44	46·71	42·211	2·067
16	14·68	321·28	·45	46·45	42·362	2·073
18	330·42	261·76	·45	46·18	42·514	2·079
20	286·17	202·25	·46	45·92	42·665	2·085
22	241·93	142·75	·46	45·66	42·817	2·091
24	197·70	83·26	·46	45·39	42·967	2·097
26	153·48	23·78	·47	45·12	43·119	2·103
28	109·28	324·31	0·47	44·85	43·270	2·109
30	65·09	264·86	·47	44·59	43·421	2·115
1898						
Jan. 1	20·90	205·41	·47	44·32	43·572	2·121
3	336·73	145·98	·47	44·06	43·723	2·127
5	292·57	86·56	·47	43·79	43·875	2·133
7	248·42	27·14	·46	43·52	44·026	2·139
9	204·28	327·74	·46	43·26	44·177	2·145
11	160·15	268·36	·45	42·99	44·328	2·151
13	116·04	208·98	0·45	42·74	44·479	2·156
15	71·93	149·61	·44	42·47	44·631	2·162
17	27·84	90·26	·43	42·22	44·781	2·167
19	343·76	30·92	·42	41·96	44·933	2·173
21	299·69	331·58	·41	41·71	45·084	2·178
23	255·63	272·26	·40	41·46	45·235	2·184
25	211·57	212·95	·38	41·22	45·387	2·190
27	167·53	153·65	·37	40·97	45·537	2·195
29	123·51	94·35	0·36	40·74	45·688	2·201
31	79·49	35·07	·34	40·50	45·840	2·206

Greenwich Noon.	P	L−O	B	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d	w	B'
1898.	°	°	°	"	"	"	°	°	°
Feb. 2	24·881	54·665	2·655	41·35	·24	38·77	8·66	267·05	2·83
4	24·887	54·602	2·662	41·58	·23	38·97	8·45	266·96	2·84
6	24·894	54·525	2·668	41·80	·22	39·18	8·23	266·87	2·85
8	24·902	54·437	2·674	42·02	·20	39·40	8·00	266·77	2·85
10	24·911	54·336	2·679	42·24	·19	39·60	7·75	266·67	2·86
12	24·921	54·224	2·683	42·45	·18	39·79	7·49	266·56	2·86
14	24·931	54·100	2·687	42·66	0·17	39·98	7·22	266·44	2·87
16	24·942	53·965	2·690	42·86	·16	40·18	6·93	266·31	2·87
18	24·954	53·818	2·693	43·05	·14	40·35	6·63	266·18	2·87
20	24·967	53·661	2·695	43·24	·13	40·53	6·31	266·03	2·87
22	24·981	53·493	2·696	43·42	·12	40·70	5·99	265·86	2·87
24	24·995	53·315	2·697	43·60	·11	40·87	5·66	265·66	2·88
26	25·010	53·128	2·698	43·76	·09	41·02	5·32	265·42	2·88
28	25·026	52·931	−2·698	43·91	·08	41·16	4·97	265·15	−2·88

The constants and notation are the same as those employed last year by Mr. Marth (*Monthly Notices*, vol. lvi. No. 10, p. 516). P. denotes the position angle of *Jupiter's* axis; L−O+180° the jovicentric longitude of the Earth reckoned in the plane of the planet's equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere; Λ−O+180° the jovicentric longitude of the Sun from the same point; B, *B* the jovicentric latitudes of the Earth and Sun above the equator.

The formulæ for finding the distances of the tangents to the limbs in right ascension and declination and in other directions, and also the defect of illumination, were given by Mr. Marth in *Monthly Notices*, vol. xl. p. 490 ff, and in vol. xlv. p. 408.

The longitudes of *Jupiter's* central meridian are computed with unaltered values of the rates of rotation and of the zero meridians in the two adopted systems. The addition of the "Corr. for Phase" gives the longitudes of the meridians, which bisect the illuminated disc.

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time	A−O	B
1898.	°	°	°	m	°	°
Feb. 2	35·47	335·80	·33	40·28	45·991	2·212
4	351·47	276·53	·31	40·06	46·141	2·218
6	307·48	217·28	·29	39·85	46·293	2·223
8	263·49	158·04	·28	39·64	46·444	2·229
10	219·52	98·80	·26	39·43	46·595	2·234
12	175·55	39·57	·24	39·24	46·746	2·240
14	131·59	340·35	0·23	39·05	46·897	2·246
16	87·64	281·14	·21	38·86	47·048	2·251
18	43·69	221·93	·19	38·69	47·199	2·257
20	359·75	162·73	·17	38·52	47·350	2·262
22	315·82	103·53	·16	38·36	47·501	2·268
24	271·89	44·34	·14	38·20	47·652	2·274
26	227·96	345·15	·12	38·06	47·803	2·279
28	184·04	285·97	+0·11	37·9	47·954	−2·285

The following example illustrates the method of finding the Greenwich mean times, at which the zero meridian of either system passes the middle of the illuminated disc :—

To find the passage of the zero meridian of System II. across the middle of the illuminated disc which occurs next after noon on 1898 January 1.

Longitude of central meridian corrected for Phase$=205°·88$ Defect from $360°=154°·12$. Rotation in $48^h=1,740°·57$. Hence interval after noon at which the passage takes place

$$=\frac{48^h \times 154·12}{1740·57}=4^h·2502=4^h\ 15^m·0$$

We can find subsequent passages by interpolating for the time required to rotate through 360°.

7 Vanbrugh Park Road, Blackheath :
1897 *November* 26.

Erratum in Mr. Tebbutt's paper, vol. lvii., p. 496.

Planet's App. R.A. on Dec. 1, opposite comp. star No. 1, *for* $4^h\ 41^m\ 52^s{\cdot}98$ *read* $4^h\ 41^m\ 52^s{\cdot}68$.

Errata in Prof. Safford's paper, vol. lvii.

Page 505, line 6, *for* $-0^s{\cdot}7$ *read* $+0^s{\cdot}7$.
„ „ „ 7, *for* $-0^s{\cdot}76$ *read* $+0^s{\cdot}76$.
„ „ „ 9 from bottom, *for* the standard chronographic transits *read* his own chronographic transits.
„ 506, line 12 from bottom, *for* $e' - c = 0{\cdot}03$ *read* $c' - e = -0{\cdot}03$.
„ 507, lines 4, 5, 6 *omit* and W. Ellis to end of paragraph.
„ 508, line 9 from bottom, page 509, lines 5, 15, 19, and page 512, line 3, *for* H *Cephei* 51 *read* 51 H *Cephei.*
„ 509, lines 7 and 9 from bottom, *for* χ *read* x.
„ 511, line 3, *for* $0^s{\cdot}025$ *read* $0^s{\cdot}025$ sec δ.
„ „ „ 13 *for* $0^s{\cdot}019$ *read* $0^s{\cdot}019$ sec δ.
„ 512, „ 8, *for* $0^s{\cdot}006$ *read* $0^s{\cdot}006$ sec δ.
„ „ „ 9, *for* $0^s{\cdot}010$ or $0^s{\cdot}012$ *read* $0^s{\cdot}010$ sec δ or $0{\cdot}012$ sec d.
„ „ „ 15 from bottom, *for* $0^s{\cdot}026$ *read* $0^s{\cdot}026$ sec δ.
„ „ „ 13 from bottom, *for* $0^s{\cdot}042$, $0^s{\cdot}015$, and $0^s{\cdot}025$ *read* $0^s{\cdot}042$ sec δ, $0^s{\cdot}015$ sec δ, and $0^s{\cdot}025$ sec δ.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. DECEMBER 10, 1897. No. 2

SIR R. S. BALL, LL.D., F.R.S., PRESIDENT, in the Chair

William James Stewart Lockyer, M.A., Ph.D., 16 Penywern Road, South Kensington, S.W.,

was balloted for and duly elected a Fellow of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Samuel Cooke, M.A., Principal of the College of Science, Poona, India, 2 Mortimer Road, Clifton, Bristol (proposed by Sir R. S. Ball);
Thomas Charlton Hudson, B.A., Assistant, Nautical Almanac Office, 3 Verulam Buildings, Gray's Inn, W.C. (proposed by A. M. W. Downing);
David Hunter, John O'Groat's Villa, Cambuslang, Glasgow (proposed by John Dansken);
Alfred E. Larkman, Navigation Teacher, 56 Colville Road, Leytonstone, E. (proposed by W. E. Plummer);
Edmund Taylor Whittaker, B.A., Fellow of Trinity College, Cambridge (proposed by Sir R. S. Ball);
Walter Wickham, First Assistant, Radcliffe Observatory, Oxford (proposed by A. A. Rambaut).

Eighty presents were announced as having been received since the last meeting, including, amongst others :—

A $3\frac{1}{4}$-inch Equatorial Telescope, by Ross, with tripod stand, micrometer, &c., presented by Mrs. Mann ; W. F. Denning, The Great Meteoric Shower of November ; C. E. Peek, Variable Star Notes, No. 2 ; G. Johnstone Stoney, On Atmospheres upon Planets and Satellites, presented by the Authors ; Bonn Observatory, Eigenbewegungen von 335 Sternen, von F. Küstner ; Lick Observatory, Photographic Atlas of the Moon, plates 6–19, presented by the Observatories ; Photographs of nebulæ made with 24-inch reflector (lantern slides), presented by Mr. W. E. Wilson.

A determination of the Latitude-Variation and of the Constant of Aberration, from observations made at the Royal Observatory, Cape of Good Hope, 1892–94. By W. H. Finlay, M.A.

In the early part of 1892 a series of observations with the zenith telescope was commenced by Dr. Gill, for the purpose of determining the latitude-variation at the Cape, and the constant of aberration ; but pressure of other work led him to transfer the investigation to me at the end of the year.

Observations were continued throughout 1893 and 1894, but no use has been made of those taken after 1894 April. At this date the ether in the level suddenly evaporated to such an extent as to render work impossible. An attempt was made to refill the tube on the spot and observations were continued, but the result was not satisfactory : the bubble became very sluggish and sticky in places, so that the observations after this operation are affected with large accidental errors, and are not nearly comparable in accuracy with the earlier ones. Indeed, it may be said that the level was a weak point all through.

The value of one revolution of the micrometer-screw was determined from a number of transits of close polar stars at elongation, and the screw errors were carefully investigated.

Three groups of stars, each consisting of three pairs, were selected at R.A. 7^h, 15^h, 23^h respectively, and another three at R.A. 3^h, 10^h, 19^h. The programme laid down was that eight observations of one of these groups should be made soon after sunset, and eight of another before sunrise, as nearly as possible on the same dates. Care was also taken to secure as many sets starting "lamp east" as starting "lamp west." The total number of pairs observed was 621.

The reductions to apparent place were interpolated for the time of transit, and the small terms depending on the Moon's longitude were taken into account. The proper motions were

adopted from a discussion of all the available declinations of the stars, and in some cases they proved to be considerable—*e.g.* Lac. 2437, $-''\cdot334$: Lac. 2608, $+''\cdot370$: L[1] Puppis, $-''\cdot118$: Lac. 8109, $-''\cdot16$.

From every observation of a pair a correction to the adopted latitude was obtained, and the means of about four nights were taken for investigation. These were all considered to have equal weight, as no observations of a group were included unless at least two pairs were observed.

For a general solution the equations of condition were put in the form

$$C + x \cos M + y \sin M + x' \cos N + y' \sin N - A\rho = n,$$

where C is a constant for each group and depends on the assumed declinations of the stars and the adopted mean latitude : x, y, x', y' are coefficients of the periodic variation of latitude.

M and N are angles which go through their periods uniformly in 427 days and 365 days respectively, and are reckoned from 1893·0.

A is the mean of the aberration terms in the stars' reductions to apparent place, divided by 20·445.

ρ is the correction to the constant of aberration ($20''\cdot445$).

n is the mean of the observed corrections to the assumed latitude.

It was not anticipated that there would be any sensible personal equation between the two observers, and no particular care was taken to secure a comparison between them. Both observers took part in the observations of groups 4 and 5 at the end of 1892 and beginning of 1893. A comparison of these few results would seem to indicate that a correction of $-0''\cdot15$ has to be applied to observations by G to reduce to the standard of F, but the observations are too few to settle this point. A term G has therefore been introduced into the equations of condition for 1892, in order to represent the relative personal equation.

From all the equations of a group normals were formed in C, x, y, &c., and the value of C derived from its normal in terms of the other quantities was then substituted in the other normals. In this way each group gave six sub-normals in x, y, x', y', G and ρ. The mean of all the sub-normals in x was then taken for the final equation in x, and similarly for the other quantities.

The solution of these equations gave

$$x = +''\cdot240 \pm ''\cdot023 \qquad y = +''\cdot080 \pm ''\cdot024$$
$$x' = -\cdot135 \pm \cdot025 \qquad y' = -\cdot227 \pm \cdot025$$
$$G = +\cdot004 \pm \cdot017 \qquad \rho = +\cdot131 \pm \cdot020$$

The coefficient of the annual term comes out considerably larger than found by Chandler, but this series is hardly long enough to distinctly separate the 427 and 365 days periods.

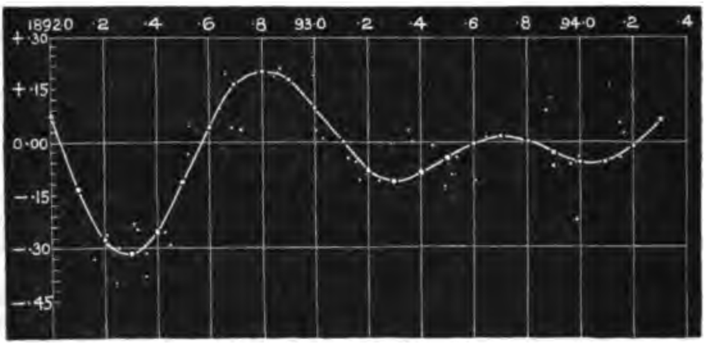
The probable error of a single equation (mean of three pairs on four nights) is $\pm''\cdot055$; so that the probable observational error of a single latitude from one pair is $\pm 0''\cdot168$.

The following table gives the variations of latitude as computed from the above solution:—

TABLE I. (*values of* $\phi - \phi_0$)

1892·0	$+''\cdot076$	1892·8	$+''\cdot207$	1893·6	$-''\cdot001$
·1	−·131	·9	+·184	·7	+·016
·2	−·277	1893·0	+·102	·8	+·001
·3	−·316	·1	+·004	·9	−·029
·4	−·253	·2	−·075	1894·0	−·054
·5	−·114	·3	−·098	·1	−·051
·6	+·043	·4	−·083	·2	−·010
·7	+·166	·5	−·042	·3	+·062

This curve is laid down on the accompanying diagram, and the dots show the separate results from the various groups.



The value of the aberration-constant from the above solution is larger than has been generally obtained, but the observations admit of this quantity being determined with almost entire freedom from error due to latitude-variation. There are twelve combinations of simultaneous evening and morning groups available for this purpose, but in a few cases there is a slight want of absolute coincidence in epoch. To allow for this a solution was made putting $\rho = 0$, and the quantities in the fourth column of the following table have been applied to the absolute terms of the equations. These corrections are in every case very small and have no appreciable effect on the result.

The equations are :—

TABLE II.

Group.	Date.	No. of Nights.	$\delta d\phi$	Equation of Condition.	ρ
1	1892·19	10	$-0''\!\cdot\!28$	$C_1 - C_2 + \cdot741\rho = -''\cdot004$	$+''\cdot157$
2	1892·22	8			
5	1892·35	10	·000	$C_5 - C_6 + \cdot955\rho = +\cdot036$	$+\cdot188$
6	1892·35	8			
2	1892·47	10	·000	$C_2 - C_3 + \cdot985\rho = +\cdot348$	$+\cdot158$
3	1892·47	8			
4	1892·68	9	$-\cdot010$	$C_4 - C_6 - \cdot875\rho = -\cdot276$	$+\cdot131$
6	1892·67	9			
1	1892·86	6	·000	$C_1 - C_3 - \cdot849\rho = -\cdot045$	$+\cdot154$
3	1892·86	8			
4	1893·00	9	$-\cdot005$	$C_4 - C_5 + \cdot767\rho = +\cdot078$	$+\cdot110$
5	1893·01	8			
1	1893·14	9	$-\cdot021$	$C_1 - C_2 + \cdot761\rho = +\cdot021$	$+\cdot185$
2	1893·17	8			
5	1893·27	8	$+\cdot001$	$C_5 - C_6 + \cdot930\rho = -\cdot077$	$+\cdot071$
6	1893·36	8			
2	1893·47	8	$+\cdot013$	$C_2 - C_3 + 1\cdot035\rho = +\cdot301$	$+\cdot106$
3	1893·52	9			
1	1893·90	8	$+\cdot008$	$C_1 - C_3 - \cdot793\rho = -\cdot004$	$+\cdot113$
3	1893·87	5			
4	1893·97	8	$-\cdot001$	$C_4 - C_5 - \cdot710\rho = +\cdot102$	$+\cdot152$
5	1893·98	9			
1	1894·13	8	$+\cdot014$	$C_1 - C_2 + \cdot748\rho = -\cdot083$	$+\cdot050$
2	1894·16	8			

Now the combinations of groups 1, 2 and 3 close, also those of groups 4, 5 and 6. Taking, then, these series independently, we have in the mean :—

TABLE III.

$C_1 - C_2 + 0\cdot750\rho = -''\cdot022$	$C_4 - C_5 + 0\cdot738\rho = +''\cdot090$
$C_2 - C_3 + 1\cdot010\rho = +\cdot324$	$C_5 - C_6 + 0\cdot943\rho = -\cdot021$
$C_3 - C_1 + 0\cdot821\rho = +\cdot021$	$C_6 - C_4 + 0\cdot875\rho = +\cdot276$

therefore, by addition,

$$2\cdot581\rho = +\cdot323 \qquad\qquad 2\cdot556\rho = +\cdot345$$

and $\rho = +\cdot125 \qquad\qquad \rho = +\cdot135$

In the second of these series there is only one combination of groups 6 and 4, so that slightly greater weight should be given to the result of the first.

Substituting $\rho = +0''\cdot13$ in the equations of Table III. we find the values of $(C_1 - C_2)$ &c., and the substitution of these in Table II. leads to the separate values of ρ given in the last column of that table. The weighted mean of these is $+''\cdot131$, and its probable error $\pm''\cdot008$. These values of $(C_1 - C_2)$ &c. agree very closely with those found from the first general solution.

In the case of some of the stars the material available for the determination of proper motion is scanty, and it is quite possible that in a few cases the adopted motion may be $''\cdot01$ or $''\cdot02$ in error, but in the mean the result for ρ cannot be sensibly in error from this cause.

The constant of aberration, therefore, from this series of observations is $20''\cdot57 \pm 0''\cdot01$.

Royal Observatory, Cape of Good Hope:
1897 *October.*

Additional Note on Personal Equation. By Truman Henry Safford, Field Memorial Professor of Astronomy in Williams College.

In a former paper I have shown that the two-method personal equation is, on the average, about $0^s\cdot13$ to $0^s\cdot20$ for the ordinary time stars observed at Greenwich, and that it is persistently positive; or, in other words, that the average Greenwich observer anticipates by eye and ear the time of his own chronographic transits by an amount nearly equal to the "reaction-time" to a sense impression as determined by Wundt and other psychologists. To make rather more definite the astronomical results which I have obtained is the object of the present paper.

As the subject is one which involves two sciences, the research is one which it is difficult to put in logical order.

I will begin, then, by giving the average $e'-e$ for the years 1885 to 1894 inclusive, as derived from the Introductions to the Greenwich Observations. The averages are taken, giving each observer for the year equal weight.

Year.	Mean $e'-e$. (s)	No. of Observers.	Year.	Mean $e'-e$. (s)	No. of Observers.
1885	+0·158	5	1890	+0·180	5
1886	+0·145	6	1891	+0·122	5
1887	+0·170	5	1892	+0·165	10
1888	+0·212	5	1893	+0·123	15
1889	+0·162	5	1894	+0·162	10

The mean for the ten years is $0^s{\cdot}160$, or $0^s{\cdot}03$ more than that obtained by taking the mean of the two values given in my previous paper for Mr. Downing and Mr. Lewis separately.

For the "simple reaction" it is rather difficult to find a standard average value. Wundt, in the edition of 1880 of his *Grundzüge der physiologischen Psychologie*, gives the following as his own means from many experiments :—

		s
Reaction to sound	... ...	0·167
„ light	... ...	0·222
„ electric stimulation of the skin	... ...	0·201
„ sensation of touch	... ...	0·218

Hankel found

		s
Reaction to sound	... ...	0·1505
„ light	... ...	0·2246
„ electric stimulation	... ...	0·1546

The purely astronomical mean $0^s{\cdot}160$, obtained by combining the ten years' results obtainable from the Greenwich Observations, is sufficiently near the general average of these quantities to fully corroborate the conclusions of my previous paper, viz., that the phenomena of personal equation confirm the theories of Bessel and Wundt as to its psychical nature. In fact, we must be very careful to distinguish between the personal equations by the two methods, as they arise from quite different causes,* a fact sufficiently evident when we consider the amounts, $0^s{\cdot}5$ to $0^s{\cdot}6$, which the personal equation between the two methods can reach for the same observer.

The most puzzling form of personal equation seems to be that for faint stars observed by eye and ear; and the study of that form by chronographic transits and by Bradley's method used side by side would seem to be a next step to be taken in the investigation of the entire subject.

I would call attention to some oversights in the MS. of my previous paper. In stating the polar equations of Romberg, Morine, Seraphimoff, Ditshénko and myself, the values $0^s{\cdot}026$, $0^s{\cdot}025$, $0^s{\cdot}042$ and $0^s{\cdot}006$ should be multiplied by tan δ or sec δ to give the actual time by which the observers named observe relatively too late or too early when the star is very near the pole.

Williamstown, Mass.:
1897 *November* 30.

* The variation of $e' - e$ from year to year is a marked feature for all, or nearly all, the observers, whether old or young, experienced or inexperienced. See, for example, p. 506 of my paper in the May number of the *Monthly Notices*.

Mean areas and heliographic latitudes of Sun-spots in the year 1895, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lvii. p. 2, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1895, and Table II. gives the same particulars for the entire year 1895 and the six preceding years for the sake of comparison. The areas are given in two forms. First, projected areas—that is to say, as seen and measured on the photographs—these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for fore-shortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1895 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results from 1889 to 1894 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888, on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Umbræ.	Projected Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
	d							
552	1895 Jan. 2·64	26	214	1208	1931	149	853	2137
553	Jan. 29·97	28	240	1296	1936	175	991	2136
554	Feb. 26·32	27	257	1552	1858	179	1114	2104
555	Mar. 25·63	27	183	1029	2085	138	812	2460
556	Apr. 21·91	27	211	1133	2224	158	853	2493
557	May 19·14	27	306	1764	2472	217	1280	2690
558	June 15·34	28	222	1294	2145	158	963	2380
559	July 12·54	27	217	1228	2010	143	833	2292
560	Aug. 8·76	27	267	1508	2177	195	1135	2420
561	Sept. 5·00	27	210	1206	2177	149	868	2399
562	Oct. 2·27	28	290	1641	2071	200	1175	2230
563	Oct. 29·56	27	231	1178	1793	163	851	1902
564	Nov. 25·86	27	194	1026	1847	142	787	1948

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Umbræ.	Projected Whole Spots.	Faculæ.	Corrected for Foreshortening. Umbræ.	Whole Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877
1895	364	237	1330	2059	169	974	2278

Table III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	d.			°		°	°	°
552	1895 Jan. 2·64	26	392	12·51	461	14·19	− 1·91	13·42
553	Jan. 29·97	28	506	13·69	485	11·62	+ 1·30	12·68
554	Feb. 26·32	27	605	13·07	509	9·02	+ 2·97	11·22
555	Mar. 25·63	27	551	13·66	261	11·77	+ 5·48	13·05
556	Apr. 21·91	27	604	19·13	249	15·42	+ 9·05	18·05
557	May 19·14	27	686	16·41	594	16·68	+ 1·06	16·53
558	June 15·34	28	615	15·25	348	12·11	+ 5·37	14·12
559	July 12·54	27	302	12·80	531	9·00	− 1·11	10·38
560	Aug. 8·76	27	976	13·87	159	10·43	+ 10·46	13·38
561	Sept. 5·00	27	521	13·73	347	14·63	+ 2·39	14·09
562	Oct. 2·27	28	782	14·38	392	15·07	+ 4·54	14·61
563	Oct. 29·56	27	561	11·56	290	8·04	+ 4·88	10·36
564	Nov. 25·86	27	340	13·05	447	13·22	− 1·86	13·15

Table IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
			°		°	°	°
1889	360	5·0	+ 7·26	73·0	− 11·90	− 10·68	11·61
1890	361	53·1	+ 22·20	46·3	− 21·75	+ 1·73	21·99
1891	363	401	+ 20·49	169	− 19·91	+ 8·52	20·31
1892	362	607	+ 15·09	607	− 21·69	− 3·29	18·39
1893	360	517	+ 14·91	941	− 14·26	− 3·93	14·49
1894	364	543	+ 12·31	739	− 15·56	− 3·75	14·18
1895	364	565	+ 14·26	409	− 12·54	+ 3·01	13·54

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

The Sun-spot record for 1895, as brought out by the above tables, shows some interesting points of comparison with the record for 1894.

(1) The decrease in the mean daily area of whole spots commenced in 1894 has been very distinctly continued in 1895; and this area has now fallen below those of 1882, 1883 or 1884, the years of maximum of the preceding cycle.

(2) The umbræ, which gave practically the same area for 1894 as for 1893, show for 1895 a diminution of 27 per cent.

(3) But the faculæ, which had declined very rapidly from their maximum in 1892, a year earlier than that of the spots, showed a distinct revival in 1895, their mean daily area for that year nearly rising to the same numbers as for 1893.

(4) Taking the two hemispheres separately, the decrease in the area of whole spots has been limited, as in 1894, to the southern hemisphere; the slight recovery of the northern having been further continued.

(5) In consequence of this decline of the southern hemisphere, the predominance has passed over to the northern.

(6) Little change has taken place in the mean distribution of all spots in heliographic latitude, but the general trend of movement is still towards the equator. But the mean distance from the equator is still greater than in 1883, the year of maximum of the preceding cycle.

(7) When the two hemispheres are considered separately, it is seen that this equatorial movement is wholly confined to the southern hemisphere; in the northern there has been a distinct increase in the mean latitude of the spotted area. Precisely the reverse conditions prevailed in 1894.

(8) No day in 1895 was entirely free from spots, although on November 10 but a single very small spot was seen.

Proper Motions of the three close Polar Stars Groombridge 1119, *Groombridge* 2283, *and Groombridge* 3548.

(*Communicated by the Astronomer Royal.*)

These three stars, as well as Bradley 1672 and Bradley 3147, were added to the Greenwich Clock Star list in 1896, for use in the determination of azimuth error. The stars have been very frequently observed at Greenwich during the years 1887–96, and the right ascensions and north polar distances deduced for the forthcoming new Ten Year Catalogue (1890) are taken as the standard places with which those of each of the other catalogues are compared. The proper motions of the two Bradley stars are given by Professor Auwers, and in order that the three Groombridge stars may be used for azimuth determination, it is necessary that their proper motions should also be well determined.

The right ascensions and north polar distances have been brought up to 1890 with Struve-Peters precessions, from Groombridge, Pond, Radcliffe, and as many later catalogues as were easily accessible. The precessions were computed by the trigonometrical method as given in Chauvenet's Astronomy, p. 615. The convenient arrangement of the computations given in the introduction of Carrington's Catalogue of Circumpolar Stars (1855) was adopted, and use made of the tables there given for facilitating the computation.

A correction to the right ascensions of $\frac{1}{4}\,\theta^2 \sin 2a$, where θ denotes the angle between the mean equator of the date of each catalogue and the mean equator of 1890·0, was applied to the right ascensions, as this term is omitted in Carrington's formula. No systematic corrections have been applied to any of the catalogues used.

The right ascension and the north polar distance for 1890, as determined from each of the catalogues employed, was subtracted from the corresponding right ascension and north polar distance of the Greenwich ten year 1890. The proper motions deduced from each catalogue were combined with weights proportional to the product of the number of observations and the difference of epoch. The names of the catalogues, the mean dates of the observations, the number of observations, and the right ascension and north polar distance for 1890, (i) before applying proper motion, (ii) after applying proper motion, are given below.

The Greenwich right ascensions, north polar distances and proper motions for 1890·0, are

Name of Star.	R.A. 1890·0. h m s	P.M. s	N.P.D 1890·0. ° ′ ″	P.M. ″
Groomb. 1119	7 46 51·53	−0·1198	1 2 26·24	−0·020
Groomb. 2283	15 12 49·87	−0·0072	2 20 41·51	−0·031
Groomb. 3548	21 21 28·45	+0·0319	3 25 9·33	−0·018

Groombridge 1119.

Catalogue.		Mean Date of Observations.	No. of Observations.	R.A. 1890 Uncorrected for Proper Motion.	Secs. of R.A. 1890 Corrected for Proper Motion.	Mean date of Observations.	No. of Observations.	N.P.D. 1890 Uncorrected for Proper Motion.	Secs. of N.P.D. 1890 Corrected for Proper Motion.
				h m s 7 46	s			° ′ ″ 1 2	″
Groombridge	1810	1807·1	6	67·75	57·80	1807·1	9	28·65	26·99
Pond	1832	1832·1	4	63·61	56·66	1832·2	10	27·82	26·66
Radcliffe	1845	1850·6	70	56·59	51·86	1849·5	43	26·92	26·11
Paris	1845	1850·7	10	56·16	51·44	1847·1	2	27·0	26·14
Carrington	1855	1855·0	27	55·05	50·85	1855·0	27	26·77	26·07
Greenwich	1860	1857·1	5	52·73	48·78	1857·1	5	26·41	25·75
Paris	1860	1860·2	14	50·99	47·41	1856·9	41	26·6	25·94
Brussels	1865					1862·4	4	26·84	26·29
Harvard	1865	1863·7	33	53·89	50·73				
Greenwich	1872	1871·8	8	52·92	50·74	1873·3	9	26·46	26·13
Paris	1875	1877·3	33	51·43	49·91	1876·6	17	26·58	26·31
Greenwich	1880	1883·4	6	50·18	49·39	1882·6	13	26·35	26·20
Williams College	1885	1884·4	25	52·59	51·92				
Greenwich	1890	1893·0	419	51·17	51·53	1893·1	374	26·18	26·24

$$\text{Proper Motion}\begin{cases}\text{R.A.} = -0^{s}{\cdot}1198\\ \text{N.P.D.} = -0''{\cdot}020\end{cases}$$

Groombridge 2283.

Catalogue.		Mean Date of Observations.	No. of Observations.	R.A. 1890 Uncorrected for Proper Motion.	Secs. of R.A. 1890 Corrected for Proper Motion.	Mean date of Observations.	No. of Observations.	N.P.D. 1890 Uncorrected for Proper Motion.	Secs. of N.P.D. 1890 Corrected for Proper Motion.
				h m s 15 12	s			° ′ ″ 2 20	″
Groombridge	1810	1808·1	8	45·85	46·44	1808·1	8	44·59	42·05
Radcliffe	1845	1850·5	47	51·02	51·30	1848·9	11	42·20	40·93
Carrington	1855	1855·0	12	49·54	49·79	1855·0	12	42·20	41·11
Greenwich	1860	1860·3	2	49·98	50·19	1860·0	6	42·11	41·18
Greenwich	1864	1863·5	9	49·13	49·32	1864·0	12	42·58	41·77
Harvard	1865	1864·2	30	49·66	49·85				
Brussels	1865	1867·4	2	48·58	48·74	1864·5	2	41·77	40·98
Greenwich	1872					1868·6	5	43·11	42·45
Harvard	1875	1873·0	8	49·55	49·67	1873·0	6	42·75	42·22
Greenwich	1880	1886·8	3	49·61	49·63	1886·2	5	41·67	41·55
Williams College	1385	1885·3	22	49·48	49·51				
Greenwich	1890	1893·0	232	49·90	49·88	1893·1	205	41·41	41·51

Proper Motion $\begin{cases} \text{R.A.} = +0^{s}\cdot 0072 \\ \text{N.P.D.} = -0''\cdot 031 \end{cases}$.

Groombridge 3548.

Catalogue.		Mean Date of Observations.	No. of Observations.	R.A. 1890 Uncorrected for Proper Motion.	Secs. of R.A. 1890 Corrected for Proper Motion.	Mean date of Observations.	No of Observations.	N.P.D. 1890 Uncorrected for Proper Motion.	Secs. of N.P.D. 1890 Corrected for Proper Motion.
				h m s	s			° ′ ″	″
				21 21				3 25	
Groombridge	1810	1807·8	7	25·41	28·01	1807·8	7	11·50	10·02
Radcliffe	1845	1850·9	70	27·20	28·45	1849·4	24	10·35	9·63
Carrington	1855	1855·0	19	27·71	28·83	1855·0	19	9·25	8·62
Brussels	1865	1864·5	6	27·58	28·39	1866·2	2	9·86	9·43
Greenwich 1867 &	1868	1867·7	2	28·14	28·85	1868·0	2	9·28	8·88
Harvard	1875	1873·5	10	27·77	27·98	1873·5	6	8·04	7·74
Greenwich	1880	1886·8	3	26·91	27·01	1886·5	7	9·49	9·43
Williams College	1885	1884·7	20	28·29	28·46				
Greenwich	1890	1894·2	155	28·54	28·44	1893·4	79	9·28	9·34

Proper Motion $\begin{cases} \text{R.A.} = +0^{s}{\cdot}0319 \\ \text{N.P.D.} = -0''{\cdot}018 \end{cases}$

The Binary Star h 5014. By R. T. A. Innes.

This star is identical with Piazzi 17^h 341, R.A. 17^h 59^m 36^s Dec. $-43°$ $25'.8$ (1900) mag. 5·2 from Bailey's Southern Photometry. Its motion was early recognised, but the measures of Jacob, which we can now see are mutually inconsistent, made it difficult to reconcile all the observations made into even a passable orbit. It will be understood that from Jacob's station the star can only be seen at a comparatively small altitude, and from the closeness of the components and the inferiority of the telescope used it must have been a very difficult pair to deal with. The components are very nearly equal in magnitude; on one occasion Jacob found half a magnitude of difference between them, and on several occasions I have thought the now preceding star slightly the fainter, but it is really doubtful if it is so. I have, however, added 180° to all angles since the time of Jacob, and get thus :—

	Angle.	Distance.		Nights.
	°	"		
1836·7	69·1	0·67	*h*	2–1
1856·7	312·3	0·5 ±	Jacob	1
1857·7	317·2	0·6 ±	"	1
1878·7	268·0	1·38	Melbourne	1
1880·5	259·3	0·81	Russell	1
1886·6	254·8	1·27	Pollock	1
1887·8	253·0	1·38	"	3–2
1893·6	248·1	1·02	Sellors	3
1895·6	247·3	1·47	"	3
1896·6	245·6	1·49	"	3

Some of the measures of distance seem to suffer from large errors of observation. The motion is retrograde. It will be seen that apparent periastron probably took place about 1840–1855, and that in fifty-seven years from the date of discovery half of the angular orbit was described. It looks, however, as if the period was much in excess of twice the number of years already elapsed.

The Melbourne measure, which was probably made by Mr. Ellery, was kindly communicated by Mr. Baracchi, the present Government Astronomer there.

The series of measures made under Mr. Russell's direction is very valuable. This pair has a common proper motion of $0''.14$ per annum towards 208°·6.

One of *h*'s measures is set against *h* 5013, and his identification of the star as *Brisbane* 6308 is also erroneous. The star *Brisbane* 6308 follows and is included with the pair in a low power field.

Royal Observatory, Cape of Good Hope:
1897 *November* 17.

Occultation of Ceres by the Moon on 1897 *November* 13. *Observed at the Hamburg Observatory.* By Prof. George Rümker, M.A., Director of the Observatory.

(*Communicated by the Secretaries.*)

In consequence of the communication in *Monthly Notices*, vol. lvii. No. 9, it has been possible for Dr. R. Schorr to observe the occultation with the $9\frac{1}{2}$-inch equatorial of this observatory. The planet was clearly visible before the immersion near the Moon's limb, but, unfortunately, a few seconds before occultation thin clouds covered the Moon, and the planet disappeared. The time of immersion could therefore only be estimated as $10^h\ 45^m\ 15^s$ Greenwich Mean Time, with an uncertainty of ± 5 seconds. The reappearance of the planet was well observed in a cloudless sky at $11^h\ 43^m\ 4^s{\cdot}4$ Greenwich Mean Time.

The reappearance was not instantaneous, but the light showed a distinct increase for $0^s{\cdot}1$ or $0^s{\cdot}2$. With a comet-seeker of 5 inches clear aperture the phenomena could not be observed.

Occultation of Ceres by the Moon, 1897 *November* 13, *observed at the Radcliffe Observatory, Oxford.*

(*Communicated by the Radcliffe Observer.*)

The occultation-reappearance of *Ceres* (on the Moon's dark limb) was observed here by Mr. Wickham and myself as follows:

	Observer.	Instrument.	Power.	Time Noted. h m s	Oxford Sidereal Time. h m s	Greenwich Mean Time. h m s
1897 Nov. 13	A. R.	Barclay Equat.	45	2 58 25·5	2 58 11·98	11 29 54·6
	W.	Heliometer	80	2 59 0·2	2 58 12·03	11 29 54·7

Observers' Remarks: Instantaneous (A. R.). Very good (W.).

Radcliffe Observatory: 1897 *December* 9.

Observations of Meteors on 1897 *November* 13–15, *made at the Radcliffe Observatory, Oxford.*

(*Communicated by the Radcliffe Observer.*)

On November 13 the watch for meteors was continuous from $11^h\ 15^m$ till $17^h\ 45^m$ G.M.T., when clouds quickly and permanently covered the sky.

The night on the whole was very fine, with a heavy dew. The atmosphere was very clear throughout, and the sky cloudless, except for a few short intervals.

The observers' position on the east wing of the Observatory tower commanded an uninterrupted view of the eastern half of the sky. The Moon was, however, very bright, but fortunately the observers were able to work in the shadow of the tower during the greater part of the watch.

Mr. Wickham reports :—A star chart of the region had been previously plotted, and each observer had provided himself with duplicate copies. Mr. Robinson began a watch of the eastern sky at $11^h\ 15^m$, but had only noted one sporadic meteor before he was joined about midnight by Dr. Rambaut and myself, who had been detained by the observation of the occultation of Ceres by the Moon. The number of meteors seen amounted to about forty; some were quite out of the track of the *Leonids*, and a few were too faint and rapid to leave a definite impression of their paths upon the mind. The presence of the Moon proved a serious obstacle to seeing the fainter meteors, stars less than $4\frac{1}{2}$ mag. being invisible, whilst, in the actual neighbourhood of the Moon, bright stars were recognised only with difficulty. The cluster *Præsepe* could be occasionally seen by glimpses when on the meridian.

Generally, the *Leonids* charted were fainter than the 3rd mag., with a rapidly evanescent track and a duration of about two-tenths of a second only. When bright enough for comparison with star magnitudes, notes of the estimation were made.

The rather numerous sporadic meteors were generally much brighter than the *Leonids*, and had longer and more lasting trails.

General notes by Mr. Robinson :—Stars down to mag. 4 were seen without difficulty, and others slightly fainter could be traced at times. *Præsepe* was visible at intervals, but only as a very feeble haze. The method of observation I adopted was as follows :—Immediately on the appearance of a meteor, a 13-inch pencil, held firmly at arm's length, was placed along the meteor's path, the direction, length of track, and then the approximate time estimated, and the track pencilled on a prepared chart. The chart used contained stars, down to the 4th magnitude inclusive, in *Leo* and surrounding region. A few of the meteors were not sufficiently well observed for an accurate delineation of their paths, but those recorded in the chart are considered fairly accurate in direction, although the swiftness of the phenomena rendered observations very difficult.

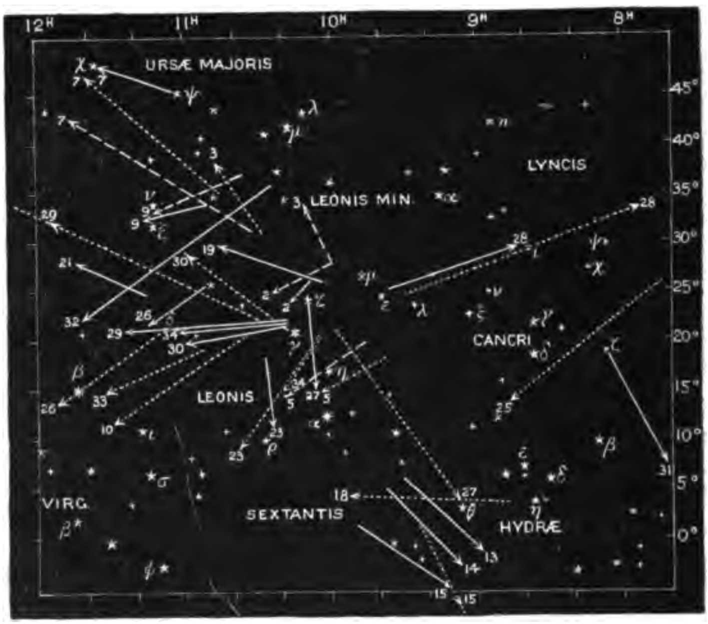
The meteors were generally between the 2nd and 3rd magnitude, the brightest, which excelled the 1st magnitude, occurring at $16^h\ 32^m$ G.M.T. Some as faint as mag. 4 were recorded, but any beyond this limit would, in most cases, be obliterated by the moonlight. Several meteors were obviously from radiants other than *Leo*, but their positions were as a rule only approximately secured.

Radcliffe Observatory, Oxford. Observation of Meteors, 1897 *November* 13.

Ref. No.	Approx. G.M.T. h m	Observers.	Observers' Notes.
1	11 42	R.	Through Castor and Pollux towards equator.
2	12 27	A. R: W.	(W.) A short flash, duration $0^s.3$.
3	12 44	A. R: W: R.	(A. R.) Time not observed; faint trail. (W.) Not charted; faint streak; 1 sec. (R.) Beads; good observation.
4	12 57	W.	Not charted; in Ursa Maj.
5	13 5	A. R: R.	(A. R.) Swift.
6	13 16	A. R.	Sporadic; through Ursa Maj.
	13 24		(Clouds passing in south.)
7	13 27	A. R: W: R.	(A. R.) Very swift; faint. (R.) Charted on the morning of the 15th from sketch and notes made at the time of observation.
8	13 32	R.	Sporadic in Ursa Maj.
	13 34		(Clouds over Leo.)
9	13 47	A. R: W: R.	(A. R.) Faint. (R.) Sporadic.
10	14 5	R.	Swift.
11	14 7	A. R: W: R.	Sporadic in Ursa Maj. (R.) Very bright.
12	14 21	W.	Sporadic in Ursa Maj.
13	14 22	W.	
14	14 23	W.	Brighter than α Hydræ.
15	14 26	W: R.	(W.) 2nd mag. (R.) 1st mag. Track approximate only.
16	14 37	R.	Across Leo; 4th mag.; swift.
17	14 42	R.	(R.) 4th mag. From Sickle to north of β Leonis.
18	14 59	R.	Sporadic.
19	15 1	W.	
20	15 4	R.	From Sickle to Castor; 4th mag.
21	15 29	W: R.	(R.) Only partially seen.
	15 40 to 15 45		(Cloudy; watched in breaks.)
22	15 47	R.	Sporadic; Capella to Sickle; 2nd mag.
23	15 52	W: R.	(W.) Brighter than 2nd mag. (R.) 2nd mag. good.
24	15 57	W: R.	Sporadic from south of Leo. (R.) 2nd mag.
25	15 59	R.	Sporadic; 3rd mag.
26	16 14	W: R.	(W.) Very swift and faint. (R.) Only approximate; very swift; 2½ mag.
27	16 32	W: R.	(W.) Similar light to magnesium; brighter than 1st mag. (R.) Brighter than 1st mag.
28	16 47	W: R.	(W.) Streak. (R.) Train; several secs. duration.

Ref. No.	Approx. G.M.T. h m	Observers.	Observers' Notes.
29	17 3	W : R.	(R.) Charted on the morning of the 15th from sketch and notes made at the time of observation.
30	17 3½	W : R.	(R.) Shorter track and slightly greater altitude than last.
31	17 11	W.	ζ Cancri to below Procyon.
32	17 17	W : R.	(W.) Very swift. (R.) Seen, but not charted; very swift; from about 10ʰ 30ᵐ R.A. Decl. + 30° towards Arcturus.
33	17 32	R.	Approximate; very swift; 3rd mag.
34	17 39	W : R.	(R.) 2nd mag.
35	17 39	W.	Sporadic.
	17 45		(Very cloudy.)

Observers: A. R., A. A. Rambaut. W., W. Wickham. R., W. H. Robinson.



Meteor Tracks, 1897 Nov. 13.
Observers: A. A. Rambaut............ W. Wickham ———
W. H. Robinson ....

The night of November 14 was overcast, with frequent rain, but on the 15th, although the sky was generally cloudy, Mr. Robinson reports that frequent breaks occurred in the neighbourhood of *Leo* between $12^h\ 45^m$ and $15^h\ 30^m$, during which interval

only one meteor was seen at $13^h\ 9^m$ G.M.T.; its track proceeding from $5^h\ 50^m$ R.A. $+40°$ Decl. to $3^h\ 40^m$ R.A. $+25°$ Decl. During the three hours' watch opportunities enough were afforded to have noted anything like a rich shower had it occurred.

On the effect of Chromatic Dispersion of the Atmosphere on the Parallaxes of a Centauri and β Orionis, and on a method of determining its effect on the Value of the Solar Parallax derived from Heliometer Observations of Minor Planets. By David Gill, C.B., LL.D., F.R.S., Her Majesty's Astronomer at the Cape of Good Hope.

In connection with the discussion of my Heliometer Observations of *Mars* in 1877 (*Mem. R.A.S.* vol. xlvi. pp. 121 and 161), I have called attention to the effect which a difference between the mean refrangibility of the light of *Mars* and that of the comparison stars might have upon the resulting value of the solar parallax.

In the determination of diurnal parallax it is unfortunately impossible to distinguish with sufficient accuracy between the refraction effect in question and a small residual error in the parallax, because, within such range of zenith distance as accurate observations can be made, the law of increase of refraction does not sufficiently differ from that of parallax.

In observations for stellar parallax it may, with proper precautions, be possible to determine the effect of different refrangibility in the mean light of two stars, because measures of distance can be made at widely different hour angles E and W of the meridian, in which such difference of refraction has opposite effects on the measured distance, whilst the parallax factor remains the same.

Professor Rambaut (*Monthly Notices R.A.S.* 1895 January, vol. lv. p. 123) discusses several series of observations of distance measures of the same pairs of stars made at widely different hour angles, and in some instances obtains a certain amount of evidence that the difference of the mean refrangibility of the light of the two stars is sufficiently great to produce in filar micrometer measures a very sensible error in the derived mean distance, if no corresponding correction is employed in computing the differential refraction.

The only difficulty in computing such corrections is to ascertain what precise wave-length (in the very short spectrum produced by atmospheric dispersion) is bisected by the observer in his observations of any particular star. Indeed, in the case of heliometer observations of the distance between two stars it is not improbable that in estimating the coincidence of the two very short spectra produced by chromatic dispersion of the atmosphere

the observer may bring the two *similarly coloured*, and not the two *brightest parts* of the star spectra into coincidence. If this be the case no correction depending upon the difference of the refrangibility of the "mean light" of the two stars would be required in heliometer observations.

The length of the visible spectrum produced by atmospheric dispersion for fairly bright stars is estimated by Airy to be $\frac{1}{60}$th part of the total refraction; or

	Length of Spectrum.
	$''$
For $\zeta=46^\circ$	1·0
57	1·5
64·3	2·0

and very refined observations cannot be made at greater zenith distances than 64° or 65°. It is obvious that, in such short spectra, the observer cannot say with certainty whether he brings into coincidence the brightest parts of the images or the parts which are similarly coloured, and two different observers may even have different habits of observation in this respect or may involuntarily make some compromise between the two methods. The only available test seems to be the actual measurements of angles under widely different conditions of refraction.

The whole question is one of very great importance, especially in connection with recent observations of minor planets for the determination of the solar parallax; and, as the observations of the planets themselves are not available for the purpose, for reasons already stated, any reliable results that can be derived from observations of stars are of special interest and importance. I also entirely concur in Professor Rambaut's conclusion that it is desirable to discuss the existence or otherwise of such a source of possible error in all refined observations for stellar parallax. But I cannot concur in the conclusions which he has drawn from his rediscussion of my own observations for the parallax of *α Centauri*.

This rediscussion is based on the fact that I found it necessary to introduce four unknown quantities in the equations of condition to express the effects of certain subjective systematic errors, and on Professor Rambaut's belief that by the introduction of a single term (expressing the effect of a difference between the mean refrangibility of the light of *α Centauri* and that of the comparison stars) a more simple and probably more correct solution is arrived at.

In the heliometer observations of *α Centauri* in question no reversing prism was employed to eliminate the possible subjective effect of the direction of measurement with respect to the vertical.* In my own experience, and I believe in that of

* The reversing prism was found to absorb an inconveniently large amount of light in the observation of the comparatively faint comparison stars as viewed through the semi-lens of a micrometer of only 4 inches aperture.

others also, it is found necessary, when working without the reversing prism, to turn the observer's head, so that the line joining the two stars under measurement is either parallel to the line joining the observer's eyes or at right angles to that line; without this precaution I am unable to estimate accurately the symmetrical passing and repassing of the star discs through each other when the position-angle handle is moved in opposite directions in the process of "crossing through." During the observations of α_2 *Centauri* I had an instinctive feeling that the pointings might be influenced to some extent by the neighbourhood of the comparison star α *Centauri*, and that this effect would be different according as the comparison appeared to the right or left, or above or below, the line joining the observer's eyes. Therefore, in the first solution, four terms, $x_{,}$, $x_{,,}$, $x_{,,,}$, $x_{,,,,}$, were introduced to represent the four subjective errors which might be expected under the four different conditions of measurement.

But in order to determine whether these assumed subjective errors are really constants, or whether they change gradually with the hour angle, a second solution was made, in which the subjective errors were represented as a periodic function of $(p-q)$, and, instead of $x_{,}$ or $x_{,,}$ or $x_{,,,}$ or $x_{,,,,}$ there was substituted in every equation

$$x+\cos(p-q)\,\alpha+\sin(p-q)\,\beta+\cos 2(p-q)\,\gamma+\sin 2(p-q)\,\delta,$$

where p is the position angle and q the parallactic angle.

These two solutions gave the following results :—

Solution I.		*Solution II.*	
$x_{,}\ x_{,,}\ x_{,,,}\ x_{,,,,}$ assumed constants.		Systematic corrections assumed a function of $(p-q)$.	
$\pi = 0''{\cdot}747$	p.e. $\pm 0''{\cdot}0133$	$\pi = 0''{\cdot}756$	p.e. $\pm 0''{\cdot}0140$
Prob. error of 1 observation	$\pm 0{\cdot}1181$	Prob. error of 1 observation	$\pm 0{\cdot}1340$

Thus the weight of an observation by Solution II. is reduced in the proportion of $(0{\cdot}1181)^2 : (0{\cdot}1340)^2$, or of $1 : 1{\cdot}3$.

The hypothesis that the systematic errors are really subjective constants (corresponding to the four directions of the line joining the observer's eyes with respect to the direction of measurement), and not a function of the hour angle, is therefore the more probable.

Professor Rambaut in his paper does not refer to this Solution II., nor to the conclusions derived from it, but he makes another solution (which we shall call Solution III.), in which the possibility of the existence of systematic errors is ignored, and a single term x, whose coefficient is $\tan\zeta \, . \, \cos(p-q)$, is introduced in place of $x_{,}$ or $x_{,,}$ or $x_{,,,}$ or $x_{,,,,}$.

The origin of this term is as follows :—

The astronomical refraction of a star of normal colour may be represented by

$$R_0 = \beta_0 \tan \zeta,$$

where ζ is the zenith distance and β_0 is a function of ζ.

For another star whose mean light is of different refrangibility we should have

$$R' = (\beta_0 + \Delta\beta) \tan \zeta.$$

In correcting any instrumental measure of the angular distance between two stars for the effects of refraction by the usual formulæ for differential refraction we take into account the term β_0 for both stars, but we omit entirely the effect of refraction depending on $\Delta\beta$; and, as the abnormally coloured star would, under identical conditions with the normally coloured star, be displaced vertically by

$$\Delta\beta \ . \tan \zeta,$$

the refraction correction in distance computed by the ordinary differential formulæ must be supplemented by the farther correction

$$\Delta\beta \ . \tan \zeta \cos (p-q).$$

Employing precisely the same observations as those used in my Solution I., Professor Rambaut finds

Solution III.

$$\pi = 0''{\cdot}780 \pm 0''{\cdot}018$$

$$x = \Delta\beta = +\overset{\text{R}}{0{\cdot}0074} \pm \overset{\text{R}}{0{\cdot}0023} = +\overset{''}{0{\cdot}095} \pm \overset{''}{0{\cdot}029},$$

and for the probable error of one observation $\pm 0''{\cdot}1686$.

If this Solution III. be a true one, it involves a most serious question in practical astronomy. Of the two comparison stars employed that named α was practically identical in colour and magnitude with α_2 *Centauri*, as viewed through the wire gauze screen which was employed in the observations; the star β is of a slightly reddish colour, and also slightly fainter than the reduced image of α_2 *Centauri* (*Mem. R.A.S.* vol. xlviii. p. 16). The value of $\Delta\beta$ found from Solution III. implies that the refraction for the principal star relative to the mean of that of the two comparison stars requires a correction of

$$+0''{\cdot}095 \ . \tan \zeta.$$

But as one of the stars is of the same colour as α_2 *Centauri*, and thence its mean refrangibility probably the same, we should have to attribute the whole of this abnormal refraction to the abnormal colour of the star β, and hence the abnormal refraction of star β would amount to

$$+0''{\cdot}19 \tan \zeta.$$

If this be true the apparent parallactic displacement of a minor planet of the same colour as the star β would be affected

by an error, due to abnormal refraction, of $0''\cdot19$ at zenith distance $45°$, or of $0''\cdot38$ at zenith distance $64°$.

It is necessary to examine Professor Rambaut's solution very thoroughly before so alarming a conclusion can be accepted.

In the first place it is a suspicious fact that the weight of an observation by Solution III. is reduced to less than one-half of its weight, according to Solution I., viz. in the proportion of $(0\cdot1181)^2 : (0\cdot1685)^2$.

Professor Rambaut attributes the very inferior representation of the observations which he obtains to the smaller number of unknown quantities which he employs, viz. four, instead of seven employed by me. This might be a valid explanation if the number of equations of condition was comparatively small; but as they are ninety-four in number, and the "sum of the squares of the residuals" has been divided, *not* by 94, but by $(94-4)$ in the case of Professor Rambaut's results, and by $(94-7)$ in the case of my own, the resulting values of the "square of the mean error" are strictly comparable.

The introduction of additional unknown quantities whose factors represent the laws of existing sources of objective or subjective error will certainly reduce the sum of the squares of the residuals; but the exclusion of terms which represent real quantities, or the introduction of terms which have no real values, must tend to increase the resulting probable error.

(A very apt practical illustration of these facts will be found in connection with the discussion of the parallax of *β Orionis* contained in a subsequent part of the present paper.)

To render subsequent discussion clear, let us suppose that a series of observations for parallax has been made in six groups, as follows :—

Group.
a Observations at first parallax maximum, hour angle E.
b Observations at first parallax minimum, hour angle W.
c Observations at first parallax zero, hour angle E.
d Observations at first parallax zero, hour angle W.
e Observations at second parallax maximum, hour angle E.
f Observations at second parallax minimum, hour angle W.

Let us farther suppose that all the observations of groups *a*, *c*, and *e* have been made at precisely the same hour angle east of the meridian, and all the observations of groups *b*, *d*, and *f* at another constant hour angle west of the meridian; we then have equations of the following types :—

Group.	
a	$x_E + (T - t_a)y + f_E \cdot \Delta\beta + f'\pi = n_a$
b	$x_W + (T - t_b)y + f_W \cdot \Delta\beta - f'\pi = n_b$
c	$x_E + (T - t_c)y + f_E \cdot \Delta\beta = n_c$
d	$x_W + (T - t_d)y + f_W \cdot \Delta\beta = n_d$
e	$x_E + (T - t_e)y + f_E \cdot \Delta\beta + f'\pi = n_e$
f	$x_W + (T - t_f)y + f_W \cdot \Delta\beta - f'\pi = n_f$

where x_E and x_W represent such systematic subjective error as may be due to the inclination to the vertical or the position of the observer's head, &c.

T is the mean epoch of all the observations ; t_a, t_b, &c., the epoch of the groups a, b, &c.

f_E and f_W the factors of $\Delta\beta$ (already defined); and, as the hour angles of all observations of the same class are identical, these factors are simply constants.

f' is the parallax factor at maximum.

n_a, n_b, &c., the absolute terms of the equations.

From these six equations, or from any number of similar equations, we can determine y, π, $(x_E+f_E\Delta\beta)$, and $(x_W+f_W\Delta\beta)$; but it is impossible to obtain the separate values of x_E, x_W, and $\Delta\beta$, because the relations of their coefficients to each other are the same in every equation in which they occur.

In order to obtain the separate value of $\Delta\beta$ it would be necessary to make observations both E. and W. of the meridian at very different hour angles, so as to vary the values f_E and f_W (which then are no longer constants, but functions of the hour angle); but by so doing we introduce the possibility of other subjective errors of the kind already described unless some method of observing (such as the use of the reversing prism) is employed to eliminate the effect of subjective errors depending on the inclination of the direction of measurement.

The most powerful method of determining stellar parallax with or without the reversing prism is therefore to adopt the plan of making all the observations at one or other of two definite hour angles, and to include in the series, not only observations at the maximum and minimum of parallax, but also a series of observations at both hour angles, the observations in which series are to be made nearly about the same epoch (*i.e.* when the parallax coefficient is nearly the same for the E. and W. observations).

We have, then, only one systematic error to discuss, viz. (x_E-x_W), and we obtain it in the simplest and most powerful manner possible, only we are unable to say whether the error so determined has its origin in subjective causes (such as some form of personality) or in objective causes (such as difference in the colour of the two stars under observation).

In a nearly continuous series of observations like that under discussion it would not be possible to make all the observations at two hour angles only, but we might make them at four different selected hour angles, in which case we should have to introduce into each equation $x_{,}$, or $x_{,,}$, or $x_{,,,}$, or $x_{,,,,}$ to represent the systematic error (subjective or objective) due to the particular hour angle at which the observation was made. Here, again, the solution would be absolutely free from systematic error as regards the determination of π, but would not give any information as to whether $x_{,}$, $x_{,,}$, $x_{,,,}$ and $x_{,,,,}$ were of subjective or objective origin.

In the observations of *a Centauri* I had assumed that the

equations resulting from the observations could be divided into four classes, viz.—

Equations involving	Sidereal Time. h m h m	
$x_{,}$	8 7 to 10 29	direction of measurement parallel to observer's eyes
$x_{,,}$	11 15 to 13 9	direction of measurement at right angles to observer's eyes
$x_{,,,}$	15 50 to 19 38	direction of measurement parallel to observer's eyes, but reversed 180°
$x_{,,,,}$	19 50 to 21 41	direction of measurement at right angles to observer's eyes, but reversed 180°

and that the subjective errors for each of these classes is constant throughout the range of that class.

Now, the point at issue between Professor Rambaut and myself is whether the true systematic errors consist of four constants, due to the four different conditions of measurement, or whether they arise from the omission on my part of a single term, $\Delta\beta$, whose coefficient is $\cos(p-q)\tan\zeta$.

The residuals from Professor Rambaut's solution and my own, divided into four groups according to the direction of measurement with respect to the line joining the observer's eyes, as described above and arranged in each group in order of the sidereal time of observation, are given in the following tables :—

RESIDUALS.

From Equations in $x_{,}$.

Rotation Number.	Sid. Time. h m	$\cos(p-q) \times \tan\zeta$.	Residuals. Gill. R	Residuals. Rambaut. R	Weight.
22	8 7	+0·49	−0·028	−0·012	$\frac{1}{2}$
23	8 52	+0·64	− 19	− 5	$\frac{1}{2}$
47	8 52	+0·64	− 1	+ 10	
30	8 56	+0·65	+ 6	+ 17	
33	8 58	+0·65	− 11	− 1	
24	9 4	+0·66	− 22	− 9	
37	9 6	+0·67	+ 4	+ 13	
27	9 7	+0·67	− 15	− 3	
46	9 8	+0·67	+ 19	+ 19	
45	9 9	+0·67	+ 23	+ 33	
32	9 10	+0·68	+ 7	+ 17	
42	9 17	+0·68	− 5	+ 5	
25	9 24	+0·69	− 7	+ 6	
34	9 31	+0·70	− 12	− 3	
35	9 31	+0·70	+ 1	+ 11	
52	9 41	+0·71	− 6	+ 5	

Rotation Number.	Sid. Time. h m	Cos $(p-q)$ $\times \tan \zeta$.	Residuals. Gill. R	Residuals. Rambaut. R	Weight.
39	9 45	+0·71	+0·002	+0·011½	
26	9 49	+0·71	− 16	− 4	
56a	9 58	+0·72	+ 14	+ 27	
88	10 4	+0·72	− 6	+ 7	½
64	10 7	+0·72	+ 12	+ 26	⅓
91	10 9	+0·72	+ 7	+ 21	
50	10 12	+0·72	− 7	+ 3	
63	10 21	+0·72	− 1	+ 13	
104	10 24	+0·72	+ 15	+ 32	
98	10 25	+0·72	+ 13	+ 28	
61	10 29	+0·73	+ 13	+ 28	
		From Equations in x_{II}.			
60	10 19	+0·72	+0·014	+0·010	
95	11 3	+0·71	− 5	− 8	
38	11 23	+0·70	+ 9	0	
97	11 28	+0·70	− 52	− 55	½
103	11 44	+0·68	+ 13	+ 13	
90	11 46	+0·68	+ 3	− 1	
54	11 47	+0·69	+ 5	− 1	
40	11 53	+0·69	− 11	− 10	
101	11 56	+0·67	+ 14	+ 13	
59	11 56	+0·67	− 1	− 5	
55	11 55	+0·67	+ 14	+ 9	½
43	12 7	+0·66	+ 3	− 11	
31	12 47	+0·60	− 7	− 15	
36	13 9	+0·57	− 8	− 16	
		From Equations in x_{III}.			
2	15 50	+0·18	+0·005	−0·017	
1	16 30	+0·04	+ 16	− 4	
44	16 42	0·00	+ 13	− 11	
5	16 42	−0·04	0	− 19	
7	16 50	−0·04	+ 10	− 8	
76	17 19	−0·16	+ 4	− 8	½
105	17 24	−0·18	+ 9	− 6	
10	17 26	−0·19	+ 8	− 7	
74	17 29	−0·20	− 35	− 47	½
96	17 35	−0·23	− 8	− 25	½
93	17 45	−0·28	− 32	− 49	½

Rotation Number.	Sid. Time. h m	Cos $(p-q)$ $\times \tan \zeta$.	Residuals. Gill. R	Residuals. Rambaut. R	Weight.
62	17 45	−0·28	−0·015	−0·034	
92	17 51	−0·31	− 13	− 30	
73	17 53	−0·32	+ 4	− 9	½
102	18 5	−0·38	− 25	− 39	
4	18 6	−0·38	+ 4	− 13	
9	18 7	−0·39	− 2	− 16	
94	18 8	−0·39	+ 3	− 13	
81	18 9	−0·40	− 22	− 32	½
49	18 17	−0·44	+ 18	− 2	
3	18 25	−0·49	− 12	− 28	
79	18 29	−0·51	+ 2	+ 7	
100	18 29	−0·51	− 2	− 16	
51	18 37	−0·56	0	− 19	
13	18 37	−0·56	+ 19	+ 7	
78	18 38	−0·57	+ 2	− 7	½
53	18 40	−0·58	+ 2	− 17	
6	18 42	−0·59	− 4	− 19	
68	18 42	−0·59	− 6	− 19	
82	18 43	−0·60	+ 4	− 4	
11	18 49	−0·63	+ 9	− 3	
83	18 55	−0·67	− 14	− 21	
84	19 1	−0·71	+ 2	− 5	
14	19 7	−0·75	− 16	− 28	
70	19 10	−0·77	+ 16	+ 5	
71	19 16	−0·82	− 2	− 12	
12	19 20	−0·84	+ 9	− 1	
80	19 21	−0·85	− 3	− 10	
67	19 25	−0·88	+ 5	− 5	
99	19 35	−0·96	− 4	− 25	
58	19 38	−0·98	+ 13	0	

From Equations in x_{IIII}.

85	19 50	−1·08	−0·008	+0·018	½
17	20 4	−1·20	+ 14	+ 36	
69	20 10	−1·26	− 7	+ 17	
19	20 11	−1·27	− 15	+ 8	
87	20 21	−1·37	+ 39	+ 67	
57	20 22	−1·38	+ 20	+ 40	

Rotation Number.	Sid. Time. h m	Cos $(p-q)$ $\times$ tan ζ.	Residuals. Gill. R	Rambaut. R	Weight.
56	20 27	-1.43	-0.002	$+0.018$	
86	20 39	-1.55	$-$ 23	$+$ 5	
72	20 41	-1.58	$-$ 11	$+$ 15	
20	20 45	-1.62	$-$ 38	$-$ 15	
75	21 1	-1.82	$+$ 25	$+$ 55	$\frac{1}{2}$
21	21 3	-1.83	$+$ 3	$+$ 28	
18	21 41	-2.39	$+$ 9	$+$ 40	

A single glance at these tables is sufficient to show that Professor Rambaut's solution gives no adequate representation of the observations.

Of his twenty-seven residuals from the equations in $x_{,}$ only seven are negative.

Of his fourteen residuals from the equations in $x_{,,}$ only four are positive.

Of his forty-one residuals from the equations in $x_{,,,}$ only three are positive.

Of the thirteen residuals from the equations in $x_{,,,,}$ only one is negative; and in every case all his exceptional residuals are very small.

The means of the residuals of the four groups are :—

From equations in	$x_{,}$ R	$x_{,,}$ R	$x_{,,,}$ R	$x_{,,,,}$ R
Gill	-0.0001	$+0.0008$	$+0.0001$	$+0.0002$
Rambaut	$+0.0111$	$-$ ·0042	$-$ ·0139	$+$ ·0246

In fact, so far from eliminating my systematic errors, Rambaut's mean residuals for the four different classes of observation are, on the whole, actually larger than the systematic corrections found by me, viz.—

$x_{,}$ R	$x_{,,}$ R	$x_{,,,}$ R	$x_{,,,,}$ R
$+0.0178$	-0.0003	-0.0214	$+0.0093$

and, most remarkable of all, his representation of Group $x_{,,,,}$, where the coefficients cos $(p-q)$ tan ζ are largest, and where, therefore, his correcting term should have the largest correcting influence, is the group which is worst represented, and has the largest mean residual. Solution I., on the other hand, represents the observations with remarkable accuracy, and the + and − residuals are, on the whole, very evenly distributed.

It has already been shown that if all the observations of the same group had been made at the same hour angle, and the four groups had been observed at four different hour angles, we should, by the introduction of our four unknown quantities, have a determination of π absolutely free from suspicion of systematic error; but there would be no means of distinguishing between subjective error and error depending on $\Delta\beta$.

But as in each of the four groups the observations extend over a considerable range of hour angle, it remains to determine whether $x_{,}$, $x_{,,}$, &c. vary with the hour angle in such a way as to point to a real effect depending upon $\Delta\beta$.

No conclusions can be drawn from mere inspection of the residuals. Rambaut (*loc. cit.*) has given the value of

$$\cos (p-q) \tan \zeta,$$

which is the coefficient of $\Delta\beta$, and accordingly with these coefficients and the original equations the terms in the normals and the normal equation in $\Delta\beta$ have been computed. The complete normals are :—

$+24{\cdot}50x_{,}$				$+8{\cdot}04y$	$+6{\cdot}86y'$	$+15{\cdot}99z$	$+16{\cdot}84\Delta\beta$	$=+2{\cdot}16^{\mathrm{R}}$
	$+13{\cdot}00x_{,,}$			$+7{\cdot}99$	$+8{\cdot}35$	$+9{\cdot}32$	$+8{\cdot}72$	$=+9{\cdot}99$
		$+37{\cdot}00x_{,,,}$		$+12{\cdot}61$	$+18{\cdot}82$	$-8{\cdot}69$	$-17{\cdot}64$	$=-1{\cdot}76$
			$+12{\cdot}00x_{,,,,}$	$+2{\cdot}71$	$+2{\cdot}53$	$-6{\cdot}64$	$-18{\cdot}33$	$=-0{\cdot}62$
$+8{\cdot}04$	$+7{\cdot}99$	$+12{\cdot}61$	$+2{\cdot}71$	$+36{\cdot}56$	$+37{\cdot}32$	$+14{\cdot}95$	$+0{\cdot}19$	$=+1{\cdot}42$
$+6{\cdot}86$	$+8{\cdot}35$	$+18{\cdot}82$	$+2{\cdot}53$	$+37{\cdot}32$	$+47{\cdot}59$	$+11{\cdot}11$	$-1{\cdot}55$	$=+0{\cdot}84$
$+15{\cdot}99$	$+9{\cdot}32$	$-8{\cdot}69$	$-6{\cdot}64$	$+14{\cdot}95$	$+11{\cdot}11$	$+48{\cdot}42$	$+32{\cdot}85$	$=+5{\cdot}65$
$+16{\cdot}84$	$+8{\cdot}72$	$-17{\cdot}64$	$-18{\cdot}83$	$+0{\cdot}19$	$-1{\cdot}55$	$+32{\cdot}85$	$+58{\cdot}26$	$=+4{\cdot}09$

Eliminating from these equations the values of $\Delta\beta$ and z, with their weights, we get :—

$$\Delta\beta = -0^{\mathrm{R}}{\cdot}0012. \quad \text{Weight } 4.$$
$$z = +0{\cdot}1091. \quad \text{,,} \quad 22.$$

From Solution I., $z = +0^{\mathrm{R}}{\cdot}1092$, which differs only $-0^{\mathrm{R}}{\cdot}0001$ from the above solution, so that the difference would in no case influence the residuals in the third decimal place. The value of $\Delta\beta$ is so small that it would change the residuals only $0^{\mathrm{R}}{\cdot}002$ in a few of the equations of the group in $x_{,,,,}$, and would change the majority of the residuals by $0^{\mathrm{R}}{\cdot}001$ or less. The values of the other unknown quantities and the probable error of one observation will therefore remain sensibly the same as in the original solution.

Remembering that $1^{\mathrm{R}} = 12''{\cdot}865$, and $\pi = \dfrac{z}{1{\cdot}881}$, we have—

$$\Delta\beta = -0''{\cdot}015 \qquad \text{Prob. error } \pm 0''{\cdot}059$$
$$\pi = +0{\cdot}746 \qquad \text{,, ,, } \pm 0{\cdot}013$$

whilst the original solution gave the almost identical value

$$\pi = +0''{\cdot}747 \qquad \text{Prob. error } \pm 0''{\cdot}013.$$

Thus we find that the true value of the term $\Delta\beta$ (whose factor is $\cos (p-q) \tan \zeta$) is exceedingly small, and is determined, as might be expected, with small weight, its probable error being nearly four times greater than itself, and *its most probable value*

has the opposite sign from that derived for it by Professor Rambaut.

The important significance of this solution is—

1. That the corrections $x_{\prime}$, $x_{\prime\prime}$, $x_{\prime\prime\prime}$ and $x_{\prime\prime\prime\prime}$, introduced into the original equations, represent true subjective errors which depend upon the direction of measurement with reference to the line joining the observer's eyes, and which, within the limits of their respective groups, are independent of the zenith distance or the inclination of the line of measurement to the vertical.

2. That, within limits determinable by this series of observations, the influence of atmospheric chromatic dispersion on the measures is insensible.

3. That the value of π ($0''\cdot780$) found by Professor Rambaut is utterly at variance with the observations, and that the true value of the parallax of *α Centauri* relative to the comparison stars a and β cannot sensibly differ from $0''\cdot74$ or $0''\cdot75$.

Parallax of β Orionis.

The following observations were made by me for the determination of the parallax of *β Orionis*. The details of these and other observations connected with determination of stellar parallax will appear in vol. viii. of the *Annals of the Cape Observatory*; but as this particular series bears upon and illustrates the subject of the present paper, the results are here given and discussed.

The comparison stars employed were

$$a = \text{D.M.} - 9^\circ\cdot997 \quad \text{Mag. } 8\cdot5$$
$$\beta = \text{D.M.} - 8\cdot1078 \quad \text{,,} \quad 8\cdot4$$

And their position angles and distances from *β Orionis* are, approximately, for 1890·0—

β Orionis and a	$p = 297^\circ\cdot25$	$s = 2960''$
β	$118\cdot81$	3283

The observations were made with the 7-inch Repsold Heliometer. The image of *β Orionis* was reduced by screens to near equality of magnitude with the comparison stars. A reversing prism was employed, which in 1888 and 1889 was turned 90° after each pointing, and in 1890 after each second pointing. The observations were arranged in the order a, β, β, a, or β, a, a, β, so as to be strictly symmetrical. In the observations of 1888 and 1889 each observation consisted of four pointings (two in each of the two positions of the segments), so that each value of the distances a and β in the following table is the mean of eight pointings.

In the observation of 1890 each observation consisted of eight pointings (four in each position of the segments), so that each measured distance a or β in the following table depends on sixteen pointings; but the pointings in 1890 were more rapidly made than those of 1888 and 1889.

Three observations, made under very bad circumstances of

definition, are rejected; the others here employed were made under favourable conditions.

The observations divide themselves into five groups, viz.—

A and C made near epochs of parallax maximum at western hour angles.

B made near an epoch of parallax minimum, eastern hour angles.

D made near an epoch of zero parallax, eastern hour angles.

E made near the same epoch as D, but in western hour angles.

The readings are converted into arc with mean scale value and corrected for refraction and aberration.

The right-hand column gives the value of $\beta - \alpha$ corrected for changes in the scale value by the formula

$$\Delta(\beta - \alpha) = \frac{\beta_0 - \alpha_0}{\beta_0 + \alpha_0}\left[(\beta_0 + \alpha_0) - (\beta + \alpha)\right],$$

where β_0 and α_0 represent the mean values of the distances β and α as derived from all the observations.

1888.	α.	β.	$\beta+\alpha$.	$\beta-\alpha$ $+\Delta(\beta-\alpha)$.	Group.
March 17	2959″·848	3283″·309	6243″·16	323″·437	A
22	·543	·040	2·58	·500	
27	·680	·127	2·81	·447	
29	·569	·023	2·59	·456	
1888. Sept. 28	2959·529	3283·011	6242·54	323·487	B
29	·649	·025	·67	·375	
Oct. 1	·592	·170	·76	·572	
2	·553	·114	·67	·560	
5	·534	·093	·63	·559	
1889. March 6	2959·539	3283·166	6242·71	323·623	C
16	·462	·014	·48	·560	
21	·720	·043	·76	·317	
22	·593	·165	·76	·566	
1890. Dec. 20	2959·369	3282·981	6242·35	323·627	D
21	·436	2·991	·43	·566	
27	·472	3·190	·66	·716	
30	·552	3·081	·63	·530	
31	·485	2·977	·46	·501	
1890. Dec. 22	2959·542	3283·048	6242·59	323·509	E
30	·567	3·060	·63	·494	
31	·509	·187	·70	·680	
1891. Jan. 1	·480	·108	·59	·630	
2	·512	·051	·56	·543	

F

The parallax factors for measures of distance are—

β *Orionis* from star α ... 0·833 R . cos ($\odot - 184°·7$)

" β ... 0·873 R . cos ($\odot - 5°·1$).

The sum and difference of these factors are—

$\beta - \alpha$ ... 1·756 R . cos ($\odot - 4°·5$)

$\beta + \alpha$ ... 0·019 R . cos ($\odot - 128°·5$).

The form of the equations is—

$$x + (t - 1890)\, y + \left\{ \begin{array}{l} \tan \zeta_\beta . \cos (p_\beta - q_\beta) \\ -\tan_\alpha . \cos (p_\alpha - q_\alpha) \end{array} \right\} \Delta\beta + 1{\cdot}756 \text{ R} . \cos (\odot - 4°{\cdot}5)\, \pi = n$$

where t is the epoch of observation, p_β and p_α the position angles of the stars β and α from β *Orionis*, q_β and q_α the parallactic angle of β *Orionis* at the epochs of observation of the distances β and α respectively, and

$$n = \beta - \alpha + \Delta (\beta - \alpha) \; ... \; -323''{\cdot}540.$$

The resulting equations are :—

				Residuals (O−C). I.	II.	III.	IV.
$x - 1{\cdot}79y$	$+2{\cdot}59\Delta\beta$	$+1{\cdot}74\pi$	= − 0″·103	−0″·020	−0″·031	−0″·021	−0″·039
$x - 1{\cdot}78$	+1·19	+1·75	= − ·040	+ ·014	+ ·031	+ ·024	+ ·024
$x - 1{\cdot}76$	+1·90	+1·75	= − ·093	− ·026	− ·021	− ·021	− ·030
$x - 1{\cdot}76$	+2·57	+1·75	= − ·084	− ·004	− ·013	+ ·009	− ·021
$x - 1{\cdot}26$	−0·81	−1·76	= − ·053	− ·025	− ·023	− ·031	− ·009
$x - 1{\cdot}25$	−0·38	−1·76	= − ·165	− ·129	− ·135	− ·138	− ·121
$x - 1{\cdot}25$	−0·61	−1·75	= + ·032	+ ·064	+ ·062	+ ·055	+ ·076
$x - 1{\cdot}25$	−0·63	−1·75	= + ·020	+ ·051	+ ·050	+ ·043	+ ·064
$x - 1{\cdot}24$	−0·63	−1·74	= + ·019	+ ·048	+ ·049	+ ·042	+ ·062
$x - 0{\cdot}82$	+1·59	+1·65	= + ·083	+ ·113	+ ·119	+ ·119	+ ·120
$x - 0{\cdot}80$	+1·96	+1·73	= + ·020	+ ·057	+ ·056	+ ·060	+ ·047
$x - 0{\cdot}78$	+2·01	+1·75	= − ·223	− ·187	− ·188	− ·183	− ·197
$x - 0{\cdot}78$	+2·27	+1·75	= + ·026	+ ·067	+ ·061	+ ·069	+ ·052
$x + 0{\cdot}97$	−0·63	−0·18	= + ·087	+ ·030	+ ·046	+ ·035	+ ·047
$x + 0{\cdot}97$	−0·64	−0·15	= + ·026	− ·032	− ·015	− ·026	− ·014
$x + 0{\cdot}99$	−0·68	+0·03	= + ·176	+ ·115	+ ·135	+ ·122	+ ·136
$x + 0{\cdot}99$	−0·40	+0·10	= − ·010	− ·066	− ·050	− ·060	− ·050
$x + 1{\cdot}00$	−0·36	+0·16	= − ·039	− ·094	− ·079	− ·089	− ·080
$x + 0{\cdot}97$	+1·19	−0·02	= − ·031	− ·051	− ·071	− ·061	− ·071
$x + 0{\cdot}99$	+1·22	+0·10	= − ·046	− ·070	− ·086	− ·076	− ·086
$x + 1{\cdot}00$	+1·33	+0·16	= + ·140	+ ·118	− ·100	+ ·111	+ ·099
$x + 1{\cdot}00$	+1·29	+0·19	= + ·090	+ ·066	+ ·050	+ ·060	+ ·049
$x + 1{\cdot}00$	+1·37	+0·22	= + ·003	− ·020	− ·037	− ·026	− ·038

Giving weight $1\frac{1}{2}$ to the last two groups of equations, which depend on double the number of pointings each, and weight 1 to the rest, the normal equations are—

$$
\begin{array}{rrrrl}
+28{\cdot}0x & -1{\cdot}7y & +18{\cdot}6\Delta\beta & +5{\cdot}9\pi & =+0''{\cdot}029 \\
-1{\cdot}7 & +37{\cdot}6 & -11{\cdot}4 & -6{\cdot}1 & =+1{\cdot}407 \\
+18{\cdot}6 & -11{\cdot}4 & +50{\cdot}6 & +34{\cdot}6 & =-0{\cdot}807 \\
+5{\cdot}9 & -6{\cdot}1 & +34{\cdot}5 & +39{\cdot}7 & =-0{\cdot}447
\end{array}
$$

Of these normals the following solutions have been made :—

I. Solved for all terms.
II. Rejecting the normal and terms in $\Delta\beta$.
III. Rejecting the normal and terms in π.
IV. Rejecting the normal and terms in $\Delta\beta$ and π.

These solutions give the following values and weights of the unknown quantities :—

Solution.	x.	Weight.	y.	Weight.	$\Delta\beta$.	Weight.	π.	Weight.
	"		"		"		"	
I.	+0·014	18·0	+0·033	34·2	−0·020	12·9	+0·009	13·7
II.	+ ·004	27·1	+ ·036	36·6	...		− ·006	37·6
III.	+ ·011	21·0	+ ·034	34·7	− ·012	35·4	...	
IV.	+ ·003	27·9	+ ·037	37·5	...		...	

The substitutions of these values in the original equations give the residuals contained in the columns to the right-hand side of the equations. The corresponding values of $[p\,.\,vv]$, $\frac{[p\,.\,vv]}{n-m}$, the probable error of a single observation of weight unity, and the probable errors of the unknown quantities are given in the following table for each solution :—

Solution.	$[p\,.\,vv]$	$\frac{[p\,.\,vv]}{n-m}$	Prob. error of 1 Obs. of Weight 1.	Probable errors of x.	y.	$\Delta\beta$.	π.
I.	0·165050	0·008687	±0″·0621	±0″·0147	±0″·0106	±0″·0173	±0″·0168
II.	·169813	·008490	·0614	·0118	·0103	...	·0100
III.	·165791	·008290	·0607	·0133	·0103	·0102	...
IV.	·172825	·008230	·0605	·0115	·0099	...	...

Thus Solution IV. gives the best representation of the observations, proving conclusively that neither $\Delta\beta$ nor π have sensible values.

(We have here also a practical example of the fallacy already referred to, viz. that the representation of equations is necessarily improved by the employment of additional unknown quantities.)

The conclusion is that *β Orionis* probably belongs to a great group or system of very distant stars, to which group or system

the comparison stars α and β also belong, and the relative annual parallaxes of the stars of this group probably do not exceed $0''\cdot01$.

The mean light of β *Orionis* is also probably of the same mean refrangibility as that of the comparison stars.

In connection with both these conclusions it will be interesting to determine whether the comparison stars α and β have spectra like β *Orionis*, with the same characteristic hydrogen and helium lines.

On the somewhat improbable assumption that the value of $\Delta\beta$, as determined from Solution III., is a true quantity, and also that the observer in his heliometer pointings brings into coincidence the *brightest* parts of the dispersion spectra and not their *similarly coloured* parts, we may determine the difference in wave-length between the mean light of β *Orionis* and that of the mean light of the comparison stars.

If μ_0 is the refractive index of air of the mean wave-length for which we have computed our mean refractions, and $\partial\mu$ is the difference between the refractive index of air for light of the mean wave-length of β *Orionis* and that of the comparison stars, then

$$\partial\mu = \frac{\Delta\beta(\mu_0 - 1)}{\beta_0}$$

We have thus

$$\Delta\beta = -0''\cdot012 \pm 0''\cdot010 \text{ from Solution III.}$$

$$\left.\begin{array}{r} \mu_0 - 1 = 0\cdot00029508 \\ \beta_0 = 57''\cdot652 \end{array}\right\} \begin{array}{l} \text{as adopted by Rambaut (\textit{loc. cit.})} \\ \text{(apparently the mean of Kettler's values for D and E).} \end{array}$$

Hence

$$\partial\mu = -0\cdot00000006 \pm 0\cdot00000005,$$

which corresponds with about one 19th part of the difference of μ for light of wave-lengths D and E.

On a method of Determining the effect of Atmospheric Dispersion on the value of the Solar Parallax.

I have a strong impression that when heliometer observations are made at sufficient zenith distance for atmospheric dispersion to produce spectra of sensible length, the observer's tendency is to bring the similarly coloured parts of the spectra rather than their brightest parts to coincidence.

In observations with the filar micrometer, on the other hand, it is probable that the tendency of the observer will be to place the dark web on the brightest part of the spectrum, irrespective of colour, as Rambaut's observations of β *Cygni* and γ *Andromedæ* appear to show.

Some of my heliometer observations of *Mars* in 1877 were

made at zenith distances of 70° and upwards, and I have still a distinct recollection, in such circumstances, of the marked prismatic colouration both of the limbs of the planet and of the star discs (the length of the visible spectrum must have been then over $2''\cdot5$). I believe that in such measures I matched the colours of the spectra of the star and limb of the planet; nor do I believe that pointings which would satisfy the eye of the observer could be made in any other way. I also believe that it is on account of this method of pointing that the resulting value of the solar parallax from the Mars observations was not affected with larger systematic error.

In observations of stars, and especially where both stars are reduced by screens to approximate equality of magnitude, I believe the tendency to match the colours may be even more strongly marked.

Except in the case of *α Centauri*, where the near neighbourhood of the companion star seemed likely to produce subjective errors depending on the direction of measurement, I can find in my own observations no proof whatever of any difference between the E. and W. observations such as would be produced by atmospheric dispersion. Thus, in my observations for the parallax of *Sirius*, *ε Indi*, and *Lacaille* 952 (*Mem. R.A.S.* vol. xlviii.), and also in that of *β Orionis* just described, although $\Delta\beta$ has large factors of opposite sign on opposite sides of the meridian, the values of $x_w - x_E$ are always small, and the probable errors of their determination are as large as, and generally much larger than, the quantity itself.

It does not appear necessary to discuss these observations farther, because, with specially devised observations and modern heliometers used with the reversing prism, the question whether the positions of strongly coloured stars can be determined by heliometer observations free from the effects of chromatic dispersion can be much more conclusively settled as follows:—

Let a strongly coloured star whose declination is nearly of the same name as that of the latitude of the observatory be selected, and this star should be preceded and followed by convenient normally coloured comparison stars of nearly the same declination, situated as symmetrically as possible with respect to the coloured star. The distances of these comparison stars from the coloured star, if measured at considerable hour angles both E. and W. of the meridian, will afford large factors of $\Delta\beta$. Thus, at the Cape, suppose a red star, whose declination is $-35°$, has two comparison stars, *a* and *b*, whose position angles from it are 270° and 90° respectively, and the distances nearly equal. If these distances *a* and *b* are observed like the observations of *β Orionis*—but at 5^h hour angle, both E. and W. of the meridian—we have $\zeta = 60°\cdot3$, and $(p-q) = 157°\cdot4$ and $337°\cdot4$ for the eastern observations, and $22°\cdot6$ and $202°\ 6$ for the western. The factor of $\Delta\beta$ (viz. $\tan\zeta\cos(p-q)$) will be—

For east observations $\left\{\begin{array}{lll} \text{Star } a & \text{Factor} & -1{\cdot}615 \\ \;\;,, \;\; b & \;\;,, & +1{\cdot}615 \end{array}\right\}$ Factor for $a-b$ ... $-3{\cdot}23$

For west observations ... ... $+3{\cdot}23$

Factor W − E $+6{\cdot}46$

therefore

$$\Delta\beta = \frac{x_W - x_E}{6{\cdot}46}$$

Thus, if observations are made of the same accuracy as those for the parallax of *β Orionis* given in the present paper, we should have from one observation each E. and W. of the meridian—

$$x_W - x_E \text{ with the probable error } \pm 0''{\cdot}0605\sqrt{2} = \pm 0''{\cdot}086.$$

and we determine $\Delta\beta$ with the probable error

$$\frac{\pm 0''{\cdot}086}{6{\cdot}4} = \pm 0''{\cdot}013$$

I have accordingly selected the following coloured stars with suitable comparison stars for observation at the Cape, and another series suitable for northern observatories. This selection has, of course, been very much limited by the necessity for finding also symmetrically situated comparison stars in position angles near 90° and 270°.

It is much to be desired that heliometer observers in the northern hemisphere, *and especially those who co-operated in the observations of Iris, Victoria, and Sappho in* 1888 *and* 1889, should co-operate in this programme. From four to six observations each E. and W. should be sufficient for each set of stars. The results of such a series of observations cannot fail to throw much light upon a most fundamental question in practical astronomy. The last uncertainty in our knowledge of the solar parallax rests almost entirely on the answer which these results would give to the question, What is the limiting value of $\Delta\beta$ for the mean light of the average minor planet compared with that of the average comparison star? That value will certainly be smaller than the value of $\Delta\beta$ for the very deeply coloured stars here selected, because the difference in colour between *Victoria* and *Sappho* and their comparison stars was not perceptible when their images were juxtaposed, and, in the case of *Iris*, only Dr. Elkin noted a reddish colour in the planet.

If the results of observation should prove that $x_W - x_E$ is insensible for such highly coloured stars, then it will be certain that in his pointings with the heliometer the observer unconsciously brings the similarly coloured and not the brightest parts of the dispersion spectra into coincidence. On the other hand, if the highly coloured stars show appreciable values of $x_W - x_E$, the question arises, How are the results to be rigorously translated

into the corresponding effect of atmospheric dispersion upon the value of the solar parallax which has been determined from the observations of *Iris*, *Victoria*, and *Sappho*?

I have long had this question under consideration, and have at last found what promises to be a satisfactory solution. Let the photographic magnitudes of the stars in the proposed programme be determined by the same process which Kapteyn has employed for the magnitudes of the C.P.D., and let their visual magnitudes be also carefully determined.

Let p be the photographic magnitude of any star.
v the visual magnitude of the same star.
p_a, p_b, &c., v_a, v_b, &c., the photographic and visual magnitudes of the coloured stars a, b, &c. respectively.

Assume, for the moment, that the comparison stars of the coloured stars are of normal colour; then the proposed observations will, when discussed in the manner already described, give values of $\Delta\beta_a$, $\Delta\beta_b$, &c.

It is evident that

$(p_a - v_a)$ is a measure of what we may call the redness of star a;
$(p_b - v_a)$ is a measure of what we may call the redness of star b, &c.;

and that $\Delta\beta_a$ must be some function of p_a and v_a.
$\Delta\beta_b$ must be some function of p_b and v_b &c.

and if a linear function we should have

$$\frac{\Delta\beta_a}{\Delta\beta_b} = \frac{p_a - v_a}{p_b - v_b}$$

or

$$\Delta\beta_a = \gamma\,(p_a - v_a)$$
$$\Delta\beta_b = \gamma\,(p_b - v_a) \quad \&c.$$

where γ is a constant to be determined.

If necessary, the range of p and v can be varied by the heliometer observation of stars of different magnitudes and different depths of colour, and we may thus determine whether

$$\gamma \text{ is} = \frac{\Delta\beta}{(p-v)} + \frac{\Delta\beta}{(p-v)^2} + \&c.$$

or is some other function of p and v.

But as we know that $\Delta\beta$ is very small, we may for our present purposes assume that γ is a constant.

From the observed values of $\Delta\beta_a$, $\Delta\beta_b$, &c. and of $(p_a - v_a)$, $(p_b - v_b)$, &c. we then derive the mean value of γ.

The visual magnitude of the minor planet would, of course, be determined in the ordinary way. In determining the photographic magnitude of the planet it will be best to make two exposures upon each plate, shifting the reading of the scales of the

eye-end of the guiding telescope between the exposures, employing the planet as a guiding star in one exposure, and a fixed star as the guide in an immediately subsequent exposure of equal length. The photographic magnitude of the planet will then be obtained by comparison of the diameter of its photographic disc with the diameters of a number of star-discs on the same plate which represent stars of known visual magnitude; in fact, by a process exactly similar to that by which the photographic magnitudes of our coloured stars are determined. The results will not be affected by the real diameter of the planet, because that diameter is smaller than the granules of the film. The diameter of the planet's photographic disc will thus be the same function of its photographic magnitude as if the planet were a fixed star.

Let p_P and v_P represent the photographic and visual magnitudes of the planet.

We then have

$$\Delta\beta_P = \gamma\,(p_P - v_P),$$

where γ, p_P, and v_P have been determined.

It then only remains in the discussions of the parallax of *Iris, Victoria, and Sappho* to introduce the terms $\tan\zeta \cos(p-q)\,\Delta\beta_P$ into the equations resulting from the measures of distance, and $\tan\zeta \sin(p-q)\,\Delta\beta_P$ into those resulting from the observations of position angle, and to find the value of the $\odot^r$ parallax in terms of $\Delta\beta_P$; a matter not of very great labour when the original computations are available.

The factor with which $\Delta\beta_P$ enters into the value of the solar parallax will be, roughly, the mean tangent of the zenith distances at which the observations were made. Say, still more roughly, 1·4 (corresponding to the tangent of 55°); but as the distances of the planets are sensibly less than unity, the factor will probably come out somewhat less than 1·4. Having regard to the very large factors with which $\Delta\beta$ may be determined, and the high accuracy with which the observations can be made, there seems little doubt that, if the proposed observations are earnestly taken up, a completely satisfactory result will be arrived at.

For example. It has already been shown that if the observations for determining $\Delta\beta$ for one of the very red stars, r, can be made, under the prescribed conditions, 5^h E. & W. of the meridian *on a single night*, with the same accuracy as the observations of *β Orionis*, we should obtain from this star the value of

$$\Delta\beta_r \text{ with the probable error } \pm 0''{\cdot}013.$$

The difference between the photographic and visual magnitudes of this star may be three magnitudes (see list below), hence

$$p_r - v_r = 3,$$

and thus the probable error of the determination of γ will be

$$\frac{p.e \text{ of } \Delta\beta_r}{3} = \frac{\pm 0''\cdot 013}{3} = \pm 0''\cdot 0043 .$$

Now it is extremely improbable that the difference between the visual and photographic magnitudes of the planets will be greater than one magnitude ; so we may put

$$p_P - v_P = < 1 .$$

Hence if $\Delta\beta_P$ appears in the value of the solar parallax with the factor 1·4, we shall have

$$\left.\begin{array}{l}\text{The probable error of the determination}\\ \text{of the solar parallax, so far as it depends}\\ \text{on the uncertainty of the effect of atmo-}\\ \text{spheric dispersion}\end{array}\right\} < \pm 0''\cdot 0043 \times 1\cdot 4 = < \pm 0''\cdot 006 .$$

Of course, this result does not include the effect of the probable error of the determination of $(p_r - v_r)$ and $(p_P - v_P)$, but since these cannot exceed 0·2 or 0·3 magnitudes, and will probably be less, they must have a very small influence on the result.

At considerable zenith distances the probable error of $x_W - x_E$ will also probably be greater than that found from the observations of *β Orionis* ; but, even if that error is two or three times as great, an amply sufficient accuracy will be secured by making four or five observations, each E. & W. of four or five different sets of stars, as in the programme of observation.

It is possible that if the observers are influenced in their habit of pointing partially by the points of similar colour in the short spectra under observation and partially by the points of maximum light, the value of γ, and consequently of $\Delta\beta_P$, may be different for different observers. In this case it would only be necessary to introduce $\Delta\beta'_P$, $\Delta\beta''_P$, &c., into the corresponding equations resulting from the observations of the different observers. But, from the fact that precisely the same value of the solar parallax was obtained from the diurnal parallax of *Victoria* at the Cape alone as that derived from the combination of the Cape observations with those of the northern observatories, it seems probable that such differences, if they exist, must be very small indeed.

The sets of stars proposed for the heliometer-observation are the following :—

The photographic magnitudes for the southern stars are provisionally taken from the C.P.D. The northern stars have been selected from Krüger's *Catalog der farbigen Sterne.* The photographic magnitudes of these northern stars cannot be satisfactorily determined at the Cape, and northern observers are earnestly requested to take the necessary plates. In order that these photographic

measures of redness may be strictly comparable, it is desirable that all observers should employ the same kind of plate. The Ilford "special rapid plates," with an exposure of twenty minutes, are suggested. If such plates are sent to the Cape they will be measured and discussed there.

It is desirable to photograph not merely the red star, but to make three separate plates for each group—one having the preceding star in the centre of the plate, one having the red star in the centre of the plate, one having the following star in the centre of the plate. On each plate there may be two or three exposures separated by 1^{mm}.

Southern Heliometer Programme.

Group. Culmination at Midnight.	Magnitude. Visual.	Photo.		C.P.D. 1875.		Distance.	Position Angle.	α_0. 1900.	δ_0.
				h m s	° ′	′	°	h m s	° ′
I. Jan. 13	7·0	6·4		7 40 7·2	−37 38·5	8·2	279·8	7 41 20	−37 42
	3·5	6·8	Orange	40 48·7	39·9	11·1	78·5	7 42 19	−37 42
	6·5	6·4		41 43·3	37·7				
II. Feb. 20	7·5	8·0		10 10 53·5	−49 33·2	16·6	252·8	10 21 41	−49 38
	8·0	Not in C.P.D.*	V. red	12 31·4	28·4	17·7	93·9	10 14 25	−49 36
	8·5	8·3		14 20·1	29·6				
III. Apr. 21	8·3	8·8		13 51 41·9	−26 3·6	101·7	270·6	13 59 53	−26 11
	3·6	5·3	Deep orange	13 59 15·9	4·8	91·8	88·0	14 4 5	−26 10
	6·8	7·1		14 6 5·5	1·6				
IV. June 15	7·7	8·0		17 32 13·4	−35 34·5	83·8	273·1	17 37 20	−35 38
	8·0	9·6	Very red	39 4·1	39·0	71·0	87·0	17 43 30	−35 38
	7·1	7·6		44 33·4	35·3				
V. June 24	6·8	8·2		18 7 4·9	−29 51·4	76·9	271·0	18 11 38	−29 51
	2·8	6·2	Reddish orange	12 59·8	52·7	45·8	87·3	16 21	−29 51
	8·4	8·2		16 30·8	50·5				
VI. July 22	8·0	8·0		20 5 53·9	−21 48·8	54·7	262·8	20 9 19	−21 41
	7·7	10·4	V. v. red	9 47·0	42·1	62·6	96·0	13 29	−21 41
	7·6	7·6		14 15·1	48·5				

* The star is certainly photographically fainter than $9^{m}\cdot6$, not being visible on any of the C.P.D. plates, which contain stars of that photographic magnitude. Mag. in Z.C. 8·2, in C.G.A. 7·8; Cape 13/2 and 15/3/97. Redness = 8, mag. 8·0. Gould calls the star crimson.

Northern Heliometer Programme.

Group. Culmination at Midnight.	Magnitude. Visual.	Magnitude. Photo.		1875·0. α (h m s)	1875·0. δ (° ′)	Distance. ′	Position Angle. °	1900·0. a_o (h m s)	1900·0. δ_o (° ′)
VII. Nov. 27	6·5	...	Lal. 4549	3 58 43·0	+32 3·0	80·3	263·0	4 3 27	+32 11
	6·5	...	Kr. 328, O.R.	4 5 0·7	12·6	66·0	96·5	4 9 13	+32 12
	7·4	...	B.D. +32°, 765	10 14·9	5·2				
VIII. Dec. 9	8·1	...	B.D. +43°, 1164	4 52 38·4	+43 14·8	115·8	268·8	4 59 44	+43 18
	8·3	...	Kr. 447, R.	5 3 14·3	17·2	95·2	90·2	5 9 23	+43 19
	8·4	...	B.D. +43, 1250	5 11 57·4	16·9				
IX. Dec. 11	6·7	...	Paris 6038,	5 8 2·9	+34 10·0	56·2	271·8	5 11 57	+34 11
	7·9	...	Kr. 461, O.R.′	12 34·2	8·2	58·1	93·9	5 16 33	+34 8
	7·3	...	Paris 6222	17 14·3	4·2				
X. Dec. 28	8·3	...	W.B. 497	6 19 39·4	+38 22·5	97·9	264·5	6 25 31	+38 26
	7·0	...	Kr. 604, R.R.	27 57·1	32·6	104·8	91·9	6 34 8	+38 30
	7·5	...	Paris 8097	36 53·3	30·5				

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. JANUARY 14, 1898. No. 3

SIR R. S. BALL, PRESIDENT, in the Chair.

Edward John Griffin, Commander R.N.R., Commander R.M.S. *Moor*, Union Steamship Co., Southampton;
J. Nevil Maskelyne, 88 Trinity Road, Upper Tooting, S.W.;
Ambrose Swasey, Cleveland, Ohio, U.S.A.;
John Vaughan, Sub-Lieut. R.N.R., Commander China Navigation Co., Shanghai, and 42 Aubert Park, Highbury, N.; and
Thomas Emley Young, B.A., President of the Institute of Actuaries, 108 Evering Road, Stoke Newington, N.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Eric Doolittle, B.Sc., Assistant, Flower Observatory, University of Pennsylvania, Philadelphia, Pa., U.S.A. (proposed by T. J. J. See);
Rev. Kingsbury Jameson, M.A., Highfield, Hendon (proposed by Alfred H. Fison);
Alfred Taylor, Messrs. T. Cooke & Sons, Buckingham Works, York (proposed by Robert Wigglesworth).

Eighty-five presents were announced as having been received since the last meeting, including, amongst others :—

The collected works of Arthur Cayley, vol. xiii., presented by the Cambridge University Press; Annals of the Royal Observatory, Cape of Good Hope, vol. iii. (The Cape Photographic Durchmusterung, Part 1); vols. vi., vii. (Determination of the Solar Parallax and the Mass of the Moon from Heliometer Observations of *Iris*, *Victoria*, and *Sappho*); Results of Meridian Observations made during 1861–65 under the direction of Sir Thomas Maclear, reduced and printed under the direction of David Gill; Appendix to Cape Meridian Observations 1890–91 (Star Correction Tables by W. H. Finlay), presented by the Observatory.

On the Parallax of Sirius and of a Gruis. By David Gill, C.B., F.R.S., &c., Her Majesty's Astronomer at the Cape.

In connection with the preparation for press of a work containing determinations of the parallaxes of the 1st magnitude stars of the Southern Hemisphere, I have recently discussed a series of observations for the parallax of *Sirius* made by me with the Cape Heliometer in the years 1888 and 1889.

The results seem to be of sufficient interest for communication in a brief form to the Society. The details will appear subsequently in the *Annals* of the Cape Observatory.

The selected comparison stars were :—

γ=B.D.–16° 1593; mag. 8·7; P. angle from *Sirius*			279°·17;	S=4310″
δ=B.D.–16° 1623; „ 8·7; „ „ „			101·26;	S=4536
	Difference	...	177°·91	226″
	Sum	...		8846″

The parallax factors for the difference and sum of the distances are :—

$$\text{For } \delta-\gamma \quad 1{\cdot}997\, R \cos(\odot - 15^\circ{\cdot}6)$$
$$\delta+\gamma \quad 0{\cdot}023\, R \cos(\odot - 105^\circ{\cdot}5)$$

so that the mean position angle is nearly in the major axis of the parallactic ellipse. The pair is thus a very favourable one for our purpose, except that the comparison stars are rather too faint for the most exact measurement.

The observations were arranged symmetrically—*i.e.* in the order γ, δ, δ, γ, or δ, γ, γ, δ—so that the mean instant of observation for each distance is nearly the same.

The light of *Sirius* was diminished by suitable wire gauze screens till the reduced image was similar in every respect to the images of the comparison stars when the latter were viewed through the non-obscured segment of the object glass. The

reversing prism was used symmetrically throughout, so as entirely to eliminate any subjective error depending on the direction of measurement with respect to the vertical.

The heliometer scale readings, converted into arc with an adopted mean scale-value, were corrected for errors of the screw and scale divisions, for refraction, aberration, and proper motion to 1889·0.

The sum and difference of the two mean measured distances γ and δ were then taken for each night of observation, and the differences were then corrected for variation of scale-value on the assumption that the sum of the distances should be a constant, the correction being

$$0{\cdot}025 \quad \{8846''{\cdot}62-(\gamma+\delta)\}.$$

In only three instances did this scale-value correction amount to $0''{\cdot}01$.

Putting $(\delta'-\gamma')$ for the values of $(\delta-\gamma)$ thus corrected, and assuming the true mean value of

$$\delta'-\gamma'=226''{\cdot}100+x,$$

and adopting for the proper motion of the centre of gravity of the system of *Sirius*

$$\mu_\alpha=-0^s{\cdot}0374\,(t-1889{\cdot}0)$$
$$\mu_\delta=-1''{\cdot}2064\,(t-1889{\cdot}0)$$

and taking the orbital motion of the bright component of the system from Auwers' table, *Ast. Nach.* 3085, the following equations of condition were derived :—

		Weight.	O–C.
1888 Mar. 30	$x-0{\cdot}76y+1{\cdot}97\pi=+0''{\cdot}506-1{\cdot}52\Delta\beta$	1	−0·018
Apr. 2	$x-{\cdot}75\ +1{\cdot}99\ =+\ {\cdot}523-1{\cdot}76$	1	− ·009
23	$x-{\cdot}69\ +1{\cdot}91\ =+\ {\cdot}598-2{\cdot}06$	1	+ ·092
26	$x-{\cdot}68\ +1{\cdot}88\ =+\ {\cdot}500-1{\cdot}56$	1	+ ·004
27	$x-{\cdot}68\ +1{\cdot}87\ =+\ {\cdot}431-1{\cdot}94$	1	− ·061
Sept. 28	$x-{\cdot}26\ -1{\cdot}97\ =-\ {\cdot}821+1{\cdot}20$	1	+ ·096
29	$x-{\cdot}26\ -1{\cdot}97\ =-\ {\cdot}817+1{\cdot}10$	½	+ ·090
Oct. 1	$x-{\cdot}25\ -1{\cdot}98\ =-\ {\cdot}916+1{\cdot}42$	1	− ·006
2	$x-{\cdot}25\ -1{\cdot}99\ =-1{\cdot}019+1{\cdot}27$	1	− ·106
4	$x-{\cdot}24\ -1{\cdot}99\ =-\ {\cdot}905+1{\cdot}37$	1	+ ·008
7	$x-{\cdot}23\ -1{\cdot}99\ =-\ {\cdot}950+1{\cdot}13$	1	− ·038
1889 Mar. 24	$x+{\cdot}22\ +1{\cdot}95\ =+\ {\cdot}537-2{\cdot}38$	½	− ·033
Apr. 21	$x+{\cdot}30\ +1{\cdot}93\ =+\ {\cdot}364-2{\cdot}40$	1	− ·202
22	$x+{\cdot}30\ +1{\cdot}92\ =+\ {\cdot}849-1{\cdot}59$	½	+ ·287
23	$x+{\cdot}31\ +1{\cdot}91\ =+\ {\cdot}465-1{\cdot}50$	½	− ·095
25	$x+{\cdot}31\ +1{\cdot}89\ =+\ {\cdot}674-1{\cdot}63$	1	+ ·122

On 1888 September 29 and 1889 March 24, April 22 and 23 the images were very diffused (I 3, S 3 and 3–4), and the corresponding equations have received half weight.

In these equations

y is the correction applicable to the adopted correction for the annual change of $(\delta' - \gamma')$.

π is the parallax of *Sirius*.

$\Delta\beta$ is the correction to the constant of refraction of the principal star as compared with that of the comparison star. That is to say, if the refraction of the comparison stars in zenith distance is

$$\beta \tan \zeta,$$

that of the principal star is assumed to be

$$(\beta + \Delta\beta) \tan \zeta,$$

and the factor of $\Delta\beta$ is $\tan \zeta \cos (p - q)$.

Since the observations were not so arranged as to permit the determination of $\Delta\beta$, we find the values of x, y, and π in terms of $\Delta\beta$.

Having regard to the weights, the normal equations are :—

$$\begin{array}{rrrcrr}
+14{\cdot}00x & -3{\cdot}90y & +\ 5{\cdot}43\pi & = & -\ 0''{\cdot}498 & -\ 9{\cdot}38\Delta\beta \\
-\ 3{\cdot}90 & +3{\cdot}18 & -\ 2{\cdot}20 & & -\ 0{\cdot}007 & +\ 3{\cdot}13 \\
+\ 5{\cdot}43 & -2{\cdot}20 & +53{\cdot}01 & & +18{\cdot}640 & -45{\cdot}15
\end{array}$$

Solving these, and substituting the resulting values of x, y, and π in the original equations we get the following results :—

$$\begin{array}{llll}
x = -0''{\cdot}164 - 0{\cdot}36\Delta\beta\,; & \text{weight } 7{\cdot}4\,; & \text{probable error} & \pm 0''{\cdot}0257 \\
y = +0{\cdot}053 - 0{\cdot}02\Delta\beta\,; & \quad ,, \quad 2{\cdot}1\,; & \quad ,, \quad ,, & \pm 0{\cdot}0485 \\
\pi = +0{\cdot}370 - 0{\cdot}82\Delta\beta\,; & \quad ,, \quad 50{\cdot}7\,; & \quad ,, \quad ,, & \pm 0{\cdot}0097
\end{array}$$

$$[pvv] = 0{\cdot}1405 \qquad \frac{[pvv]}{n-3} = 0{\cdot}0108$$

and the probable error of an observation of weight unity $\pm 0''{\cdot}070$. The residuals are given in the right-hand column beside the equations.

It is very improbable that the value of $\Delta\beta$ is a sensible quantity. In the years 1881–83 I made a series of seventy-nine observations with my 4-inch heliometer (*Mem. R.A.S.* vol. xlviii. pp. 83–97) to determine the parallax of *Sirius* relative to the stars, Lal. 12936, mag. $7\frac{3}{4}$, and Lal. 13129, mag. 8, and found for the value of the parallax

$$\pi = +0''{\cdot}370\,; \text{ probable error } \pm 0''{\cdot}009.$$

In this series the systematic difference between E. and W. observations was only 0″·007, and the effect of regarding x_W as different from x_E was to change the resulting value of the parallax by only 0″·001 from that found by the assumption that none of the observations were affected by systematic error. The exact agreement of the present result with that of my previous determination—notwithstanding a difference of about 40° in position angle of the comparison stars—points also to non-existence of systematic error depending on $\Delta\beta$.

We have now from reliable heliometer observations the following results for the parallax of *Sirius* :—

		Prob. Error.	Mean. Prob. Error.
Gill	Cape 1881–83	+0″·370 ± 0″·009 *	+0″·370 ± 0″·007
	Cape 1888–89	+0·370 ± 0·0097 †	
Elkin...Cape 1881–82		+0″·407 ± 0″·018 ‡	+0″·407 ± 0″·018
		Mean	+0″·374 ± 0″·006

We may therefore regard the parallax of *Sirius* relative to average comparison stars of about $8\frac{1}{2}$ magnitude as now satisfactorily determined, and the corrections depending on a parallax of 0″·37 may with advantage be introduced in the apparent places of *Sirius* given in the national ephemerides.

Parallax of α Gruis.

It is stated above that the comparison stars employed for *Sirius* are rather too faint for the most exact measurement. In the case of *α Gruis* I found a very symmetrical pair of comparison stars of 8th magnitude, and as the observations yield the smallest residuals which I have yet met with, the results of the observations may be of interest as illustrating the accuracy attainable with a good heliometer under the most favourable conditions.

The comparison stars were

γ = G. xxi. 1712	mag. 8.	P. angle from *α Gruis*	259°·6;	distance 3670″
δ = G. xxii. 187	„ 8.	„ „ „	77·8;	„ 3510
		Difference	181°·8	160″

with the parallax factors

For $\gamma-\delta$ 1·963 R cos (☉ − 51°·5)

$\gamma+\delta$ 0·018 R cos (☉ − 22°·6)

* *Mem. R.A.S.* vol. xlviii. pp. 83–97. † Present paper.
‡ *Mem. R.A.S.* vol. xlviii. pp. 97–116.

The observations were made with the same precautions as in the case of *Sirius*. Kobold's value of the proper motion of *α Gruis* (*Ast. Nach.* 3435), based on Auwers' researches, was adopted, viz.—

$$0''\cdot205 \text{ in the direction } p\ 148^\circ\cdot8.$$

Projecting the correction for this motion on the observed distances, and forming equations of condition in the same manner as those for *Sirius*, we get :—

1888		Weight.	O−C.
Apr. 27	$x-0{\cdot}68y+1{\cdot}92\pi=+0''{\cdot}037-1{\cdot}71\Delta\beta$	1	$+0''{\cdot}032$
May 1	$x-\cdot67\ +1{\cdot}95\ =-\ \cdot082-1{\cdot}88$	1	$-\ \cdot087$
3	$x-\cdot66\ +1{\cdot}96\ =+\ \cdot119-1{\cdot}75$	1	$+\ \cdot112$
8	$x-\cdot65\ +1{\cdot}98\ =-\ \cdot049-1{\cdot}38$	1	$-\ \cdot056$
Nov. 19	$x-\cdot12\ -1{\cdot}93\ =-\ \cdot016+2{\cdot}08$	1	$+\ \cdot015$
22	$x-\cdot11\ -1{\cdot}91\ =+\ \cdot043+1{\cdot}58$	$\frac{1}{2}$	$+\ \cdot073$
27	$x-\cdot10\ -1{\cdot}88\ =-\ \cdot025+2{\cdot}05$	$\frac{1}{2}$	$+\ \cdot004$
29	$x-\cdot09\ -1{\cdot}86\ =+\ \cdot010+1{\cdot}77$	$\frac{1}{2}$	$+\ \cdot039$
Dec. 8	$x-\cdot06\ -1{\cdot}75\ =-\ \cdot103+1{\cdot}98$	1	$-\ \cdot078$
1889 May 9	$x+\cdot35\ +1{\cdot}98\ =+\ \cdot025-1{\cdot}56$	1	$-\ \cdot022$
31	$x+\cdot41\ +1{\cdot}89\ =+\ \cdot067-1{\cdot}66$	1	$+\ \cdot019$
June 3	$x+\cdot42\ +1{\cdot}85\ =+\ \cdot054-1{\cdot}58$	1	$+\ \cdot006$

On November 22, 27, and 29 the observations were made with definition 3, and the corresponding equations have received half weight.

Having regard to the weights, the normal equations are :—

$$\begin{aligned}
+10{\cdot}50x-1{\cdot}81y+\ 7{\cdot}03\pi &= +0''{\cdot}066-\ 4{\cdot}76\Delta\beta\\
-\ 1{\cdot}81\ \ +2{\cdot}26\ \ -\ \ 2{\cdot}33\ &= +0{\cdot}048+\ 1{\cdot}95\\
+\ 7{\cdot}03\ \ -2{\cdot}33\ \ +38{\cdot}27\ &= +0{\cdot}507-34{\cdot}82
\end{aligned}$$

Solving these normals and substituting the values of x, y, and π, we get the residuals given in the column headed O—C. The results are :—

$$\begin{aligned}
x &= +0''{\cdot}003+0{\cdot}18\Delta\beta\ ; \text{ weight } 9{\cdot}1\ ; \text{ probable error } \pm0''{\cdot}014\\
y &= +0{\cdot}040+0{\cdot}04\quad ; \quad ,, \quad 1{\cdot}9\ ; \quad ,, \quad ,, \quad \pm0{\cdot}030\\
\pi &= +0{\cdot}015-0{\cdot}94\quad ; \quad ,, \quad 32{\cdot}9\ ; \quad ,, \quad ,, \quad \pm0{\cdot}007
\end{aligned}$$

$$[pvv]=0{\cdot}0348 \qquad \frac{[pvv]}{n-3}=0{\cdot}00386$$

and the probable error of a single observation of weight unity $\pm0''{\cdot}042$.

The only remaining uncertainty in this result is the possible refraction effect, $\Delta\beta$, depending on the possible difference between the mean refrangibility of the light of *α Gruis* and that of the comparison stars.

As this effect, if at all sensible, must certainly depend on the difference between the types of the spectra of the principal star and the comparison star, it seems better to defer a discussion of the matter till the data referred to in a paper which I recently communicated to the Society (*Monthly Notices*, vol. lviii. p. 53) have been collected, and until I have access to the McClean telescope. The whole of this question, as it affects all these parallax researches, can then be dealt with on a broad and satisfactory basis. Meanwhile I venture to express the belief, founded on other considerations, that the value of $\Delta\beta$ will in this case not be found to amount to $0''.01$.

It may interest the more casual reader to point out the great accuracy of the individual observations which the preceding results imply.

The probable error of the single observation of difference of two opposite distances is thus :—

For *Sirius*	and comparison stars of	$8\frac{3}{4}$ mag.	$\pm 0''.070$
„ *α Gruis*	„ „	8·0 mag.	± 0.042

This implies that, as the result of one complete set of observations lasting less than an hour, the position of the principal star may be projected on the great circle joining two comparison stars with a probable error of

$\pm 0''.035$ in the case of stars $8\frac{3}{4}$ mag.

or

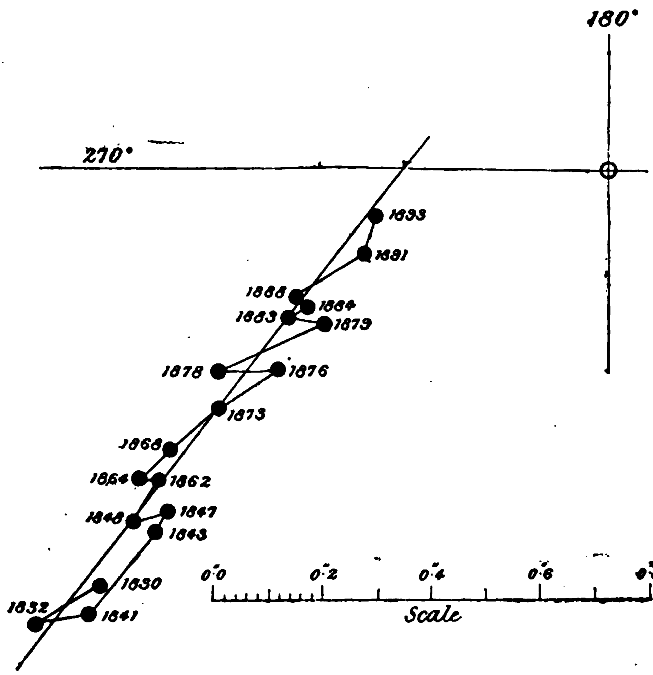
± 0.021 in the case of stars 8·0 mag.

a precision which, so far as I am aware, has not been approached by any other method of observation, nor previously attained in astronomical researches of any kind. It becomes thus possible to detect any differential stellar parallax amounting to $0''.02$ with perfect certainty by a comparatively small number of observations.

The Double Star ζ Boötis. Σ 1865. By S. W. Burnham.

This double star was discovered by Herschel a little more than one hundred years ago (=H. N. 114). In his first observation, 1796 April 5, it is described as "very nearly in contact; I can, however, see a small division." On the following evening he measured the position-angle, which is given as 41′ 59″ *n.p.*

(*Mem. R.A.S.* vol. i.); but this appears from his diagram to be a misprint for 41° 59′, giving 312° for the position-angle as now reckoned. This is the value given by Herschel II. in the Synopsis of his father's double-star observations. On the last-mentioned date Herschel says, "With 460 a division is but barely visible ¼ of S" (referring to the diameter of the smaller star). His last observation was 1807 July 12, when he noted, "The interval between their apparent disks with 460 is ⅓ of the diameter of either." The next observation appears to be by Amici in 1815 (*Zach. Corr. Astron.* vol. viii.), who measured the distance as 1″, but did not measure the angle. In 1823 South on one night measured both angle and distance, and made the latter 1″·68. He refers to Amici's distance as being "probably too small." The observations of Struve commence in 1827, and since that time this pair has been measured by most of the prominent double-star observers.



ζ Boötis. Σ 1865.

The earlier measures appeared to show little or no change, and Dawes, referring to the observations down to 1853, says: "Notwithstanding considerable discrepancies in the results, no

sufficient ground appears for suspecting relative motion. The oblique position of the components may in great measure account for the errors of observation, where no suitable precautions have been taken to avoid its effects." Since that time, however, the distance has steadily decreased, and it is now certain that the most reliable measures show a regular diminution in the distance during the entire interval. In later times it has generally been regarded as a binary of long period.

In an investigation of the character of the relative motion of these stars, it is certainly better to rely as far as possible upon the micrometrical results obtained by the most experienced observers in this field, and accordingly I have given on the diagram accompanying this paper a selection of the best measures, commencing with Struve. It will be seen from these positions that the apparent movement of the smaller component has no sensible variation from rectilinear motion. It is obvious that when this movement is not in the line of the principal star it must follow a curved path of some kind if the stars form a binary system, but the orbit might be such that the variation of the described arc from a right line could not be eliminated from the ordinary errors of observation in a pair of this class where the distance for the greater part of the time has been less than 1″.

Whether the change is due to the slow revolution of one star about the other, or to the proper motion of one or both components, the theory of rectilinear motion, at least down to the present time, will satisfy the observations with all desirable accuracy. An examination of the positions given shows that the companion star has moved 0″·89 in the direction of 142°·5 since 1831, or about 0″·0143 annually. It will be seen that these positions depend largely upon the distances alone. The change in the angle has been slow during nearly the whole interval, and the error in the measures upon any theory is therefore principally in the distances. The corrections to be applied to the observed distances in the measures shown on the diagram are as follows :—

1830·47	+0″·21	11*n*	Σ
1832·47	−0·05	3*n*	Da
1841·16	−0·10	6*n*	OΣ
1843·40	+0·07	7*n*	Ma
1847·72	+0·08	8*n*	OΣ
1848·11	−0·03	6*n*	Da
1862·95	−0·13	11*n*	OΣ
1864·78	−0·17	8*n*	Δ
1868·59	−0·16	8*n*	OΣ, Δ
1873·01	−0·12	4*n*	OΣ
1876·47	−0·03	8*n*	OΣ, Hl

1878·48	$-0''\cdot14$	2n	Δ
1879·04	+0·04	5n	Hl
1883·17	−0·06	3n	OΣ
1884·43	−0·03	3n	Hl
1888·54	−0·09	2n	OΣ
1891·31	+0·01	3n	β
1893·51	+0·03	5n	Lewis, Lv

For the most part, these corrections are as small as would be found generally in measures of a star of this class, and they cannot be materially lessened upon any other theory of motion. If the companion continues to move uniformly in the direction indicated, the minimum distance of $0''\cdot29$ will be reached about 1917.

The meridian observations of ζ *Boötis* show a small proper motion. Porter gives the annual movement as $0''\cdot030$ in the direction of $109^{\circ}\cdot6$. As this star would be apparently single in all meridian instruments, this value would probably represent the mean of the two components. Taking it as the motion of the principal star, we have the following relation between the two:—

Proper motion of A	$0''\cdot030$ in $109^{\circ}\cdot6$
Proper motion of B	$0''\cdot043$ in $119^{\circ}\cdot9$

With uniform rectilinear motion, the distance between the two stars at the time of Herschel's observations in 1796 would be $1''\cdot74$, and this agrees well with his position-angle at that time. It would seem at first that his descriptions of this pair, as already mentioned, would call for a smaller distance than that given above; but when we examine similar descriptions by Herschel of various stars of his Class I., where he has compared the distance between the components to the apparent diameter of one or the other of the stars, we find several instances where the distances at that time, as determined from the later history of the motion, could not have been less than $1''\cdot7$, so there is nothing in these early observations inconsistent with the theory of uniform motion. It will probably be a long time before the true relation of these stars is known with absolute certainty. At present it seems to belong to the 61 *Cygni* type of double stars, where the components are moving together in space, but with slightly different velocities and directions. We have now some forty or fifty of these pairs, and in most of them there is now little doubt of the relative change being entirely due to the difference of proper motion.

Yerkes Observatory:
December 13.

The Orbit of OΣ 400. By S. W. Burnham.

This close pair of the Pulkowa Catalogue, discovered by Otto Struve something more than half a century ago, was first measured by Mädler in 1843. The measures of OΣ commence in 1844, and continue at intervals down to 1861. It received special attention from Dembowski, who examined it on eleven nights 1865–77, and measured the angle whenever he could do so, but the distance was too small to be measured with his aperture. Since that time very few measures have been made. A large instrument has been necessary in recent years to show any measurable elongation.

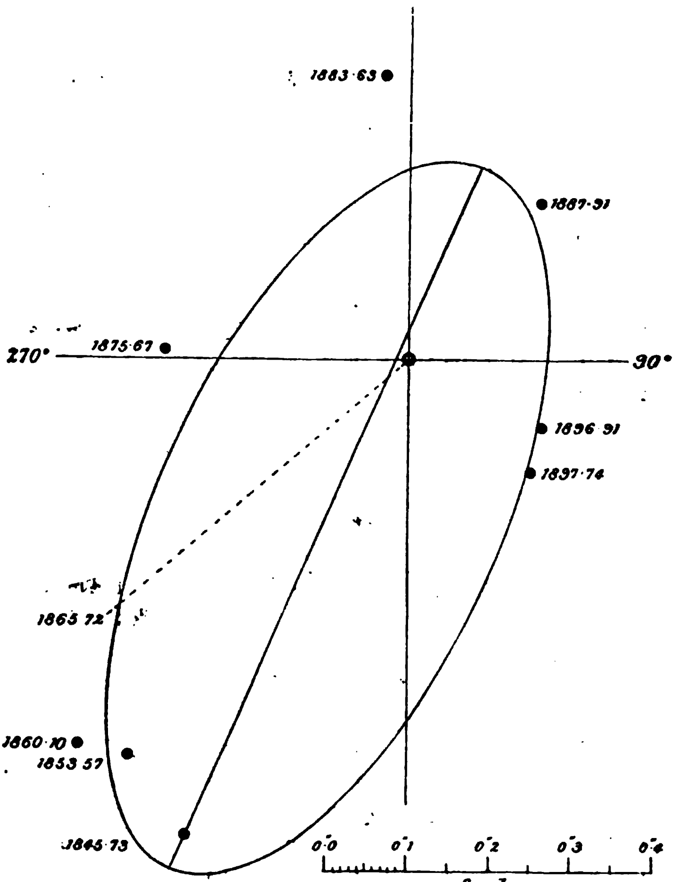
One orbit has been computed of this pair. Gore (*Monthly Notices*, xlvii. 346) from the positions to 1885 found a period of 170·37 years.

The following are all the observations of this pair:—

1843·39	326°·7	0″·5 ±	2*n*	Mädler
*1845·73	334·9	0·64	3*n*	O. Struve
*1853·25	324·6	0·59	2*n*	O. Struve
1853·89	320·5	0·65 ±	1*n*	Dawes
*1860·10	319·3	0·62	2*n*	O. Struve
*1865·72	310·7	...	2*n*	Dembowski
1868·55	301·6	obl.	1*n*	Dembowski
1871·04	301·2	oval	2*n*	Dembowski
1872·62	314·9	obl?	1*n*	Dembowski
1873·88	94·0?	obl?	2*n*	Dembowski
1874·50	107·8	obl?	1*n*	Dembowski
*1875·67	267·9	0·3 ±	3*n*	Schiaparelli
1877·59		Single	1*n*	Dembowski
1878·65		Single	1*n*	Burnham
1879·82	150·2	>0·5 ±	2*n*	Seabroke
1880·68		Single?	1*n*	Schiaparelli
1881·70		Single	1*n*	Bigourdan
1883·62		"not divided"	1*n*	Seabroke
*1883·63	185·3	0·35 ±	1*n*	Schiaparelli
1885·72	144·5	0·3 ±	2*n*	Young
1886·77	122·7	0·3 ±	1*n*	Hough
*1887·91	140·1	0·25 ±	1*n*	Schiaparelli
1892·79	300 ±	0·2 ±	1*n*	Comstock
1895·73	346·8	0·2 ±	2*n*	See
1895·76		Single	1*n*	Comstock

1896·66	°	″ Single	1n	Comstock
1896·90	67·8	0·18	2–1n	Hussey
*1896·92	63·5	0·18	3n	Aitken
*1897·74	47·3	0·20	3n	Aitken

It is evident that little use can be made of most of this material in investigating the character of the relative motion. Some of the positions are obviously erroneous or uncertain. With the recent measures made with the 36-in. at Mt. Hamilton we have a total arc of nearly 290°, which should give data for determining the elements of the orbit with substantial accuracy. The observations in the foregoing list marked (*) are shown on the accompanying diagram.



Orbit of OΣ 400.

From these positions the following elements are obtained :—

$$P = 81{\cdot}04 \text{ years}$$
$$T = 1888{\cdot}23 \text{ „}$$
$$e = 0{\cdot}46 \text{ „}$$
$$a = 0''{\cdot}47 \text{ „}$$
$$i = 59^\circ{\cdot}9 \text{ „}$$
$$\Omega = 157^\circ{\cdot}1 \text{ „}$$
$$\lambda = 7^\circ{\cdot}0 \text{ „}$$

Apparent orbit :—

Length of major axis...	...	0″·93
Length of minor axis...	...	0″·42
Angle of major axis ...	...	155°·9
Angle of periastron ...	...	153°·5
Distance of star from centre...		0″·21

The observed positions require the following corrections :—

1845·73	+ 0°·2	+ 0″·04	3n	O. Struve
1853·57	+ 2·8	+ 0·06	2n	O. Struve
1860·10	0·0	− 0·05	2n	O. Struve
1865·72	+ 0·1	...	2n	Dembowski
1875·67	+ 2·1	− 0·06	3n	Schiaparelli
1883·63	+ 2·8	− 0·13	1n	Schiaparelli
1887·91	+ 15·5	0·00	1n	Schiaparelli
1896·91	− 5·2	0·00	3n	Aitken
1897·74	0·0	0·00	3n	Aitken

It will be noticed that most of these errors are insensible quantities in measures of a close pair of this kind. The distance is now slowly increasing, and in a few years it can be measured with a moderate aperture.

The magnitudes of the components, according to O. Struve, are 7·2 and 8·2. The principal star is Lalande 38758, and its place (1875) from the Bonn Catalogue is—

R. A.	20h	6m	5s
Decl.	43°	34′	23″

It does not appear to have any sensible proper motion.

Yerkes Observatory:
December 23.

The Ternary System, Lac 7215=h 4935. By R. T. A. Innes.

As a wide pair this was observed by Sir John Herschel at the Cape in 1837, and the chief star was noted as double at Melbourne in 1867, but it was first measured as a double star some years later as β 416 and Russell 298. The chief star turned out to be a rapid binary pair with a period of 33 years according to the orbit computed by Professor See. Of Herschel's companion, which is C Z $17^{h}\cdot719$, I find the following measures :—

1837·4	130° ±	″ ...	*h*	1 night.
1875·5	130·5	29·44	Cord. Zone Catalogue.	1 „
1876·5	130 ±	...	β	1 „
1877·6	132·4	...	Russell	1 „
1889·4	128·6	31·03	β	3 „
1891·5	128·8	30·52	do.	3 „
1892·4	129·4	30·55	do.	2 „

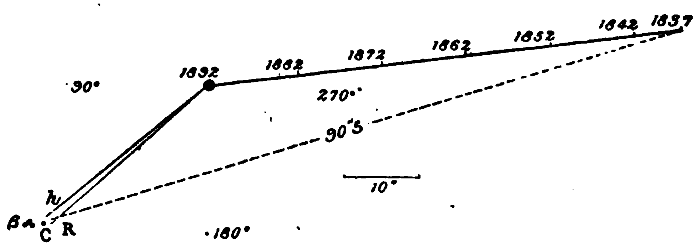
The chief star, which is yellow in colour, is *Lac* 7215 (R.A. $17^{h}\ 12^{m}\ 8^{s}$, Dec. 34° 52′·7, 1900), and has a large proper motion which is well known. The latest determination, that of Professor Porter, gives

$$\delta \text{ R.A.} = +0^{s}\cdot 0924. \qquad \delta \text{ Dec.} = -0''\cdot 161$$

or

$$1''\cdot 15 \text{ towards } 98^{\circ}\cdot 1.$$

The consideration of this proper motion shows that the Herschel companion travels with the binary pair.



The diagram will, perhaps, make the matter clearer. If both stars are animated by the same proper motion the position marked 1892 will be that of the chief star in relation to the measures of the companion, which are marked *h*, C, R, and β. The agreement is satisfactory.

If, however, the companion does not share in the proper

motion the chief star should have been found along the line marked 1892–1837.

Thus at the time of the Cordoba observation the distance, instead of being 29″ as observed, would have been about 50″, in the time of *h* about 90″, the angles as well being altered.

If we assume the mass of the close pair equal to that of the Sun, its parallax will be 0″·12; and if we now see the third star under an angle equal to its semi-axis major, its period of revolution would not be greatly different from 4,000 years.

The magnitudes of the three stars are 6·1, 8·1, and 10; but it is well to state that for the latter, estimates vary from 7 to 12—viz.

Gould	...	9·5
Russell	...	7·0
Burnham	...	10 to 12.

Royal Observatory, Cape of Good Hope:
1897 *December* 3.

The Wilsonian Theory and Mr. Howlett's Drawings of Sun-spots. By the Rev. Aloysius L. Cortie, S.J.

In Dr. Wilson's paper entitled "Observations on the Solar Spots" (*Phil. Trans. R.S.* vol. lxiv. A.D. 1774), in which his theory with regard to the cavernous nature of Sun-spots relatively to the photospheric level is propounded, he particularly calls attention to the fact that the phenomenon of the unequal foreshortening of the penumbra on either side of the umbra (or umbra and nucleus in his phraseology) is only to be observed in those spots which are not subject to any disturbance, the appearances to be expected under normal conditions being sometimes counteracted when changes have occurred in the spots during their transit across the solar disc. The Wilsonian hypothesis has lately been called in question by the Rev. Mr. Howlett, whose contention is that the Sun-spots are in general elevations above rather than depressions below the photospheric level. The admirable series of enlarged drawings of the solar spots made by this indefatigable observer have been most generously presented to the Society, and are preserved in our library. From an examination of many of these drawings it would seem that the rule that has guided Mr. Howlett in the selection of his cases against the Wilsonian hypothesis is that any spot in the neighbourhood of the limb which shows the penumbra of greater extent on the side towards the centre of the Sun is a case against the cavernous theory of the spots. In the remarks in the index which precedes each volume such expressions sometimes occur as "seemed to favour Wilson, but umbra not central and the group

actively changing." But if spots that seemingly tell for the Wilsonian theory are to be rejected and put out of court for these reasons, surely the same reasons are equally cogent in cases which tell against the theory. In fact, as Father Sidgreaves has well pointed out in his paper on this subject (*Monthly Notices R.A.S.* vol. lv. No. 5, 1895 March), no spot ought to be admitted as a suitable test in the present controversy in which the following conditions are not verified : "(1) That the spot had been observed at a position approximately between 30″ and 60″ of arc from either limb ; (2) that it had been watched on its passage between the central meridian and the limb ; (3) that it was a compact regular spot ; (4) that it showed a central umbra when remote from the limb ; and (5) that it was a quiet spot, not indicating a tendency to divide or change shape."

As the careful examination of so large a number of spots as Mr. Howlett has drawn would have taken a considerable amount of time, a volume was selected at haphazard, and the spots which are chronicled as against Wilson for the year 1883 were studied in detail. They are thus indexed :—

No.	Spot.	Date (1883).
313	η	Apr. 20
314	σ	May 11
316	ψ	June 3
317	u	June 4
320	ξ	July 18
321	β	June 30
329	ω	Sept. 4
330	ι and ζ	Sept. 8
335	δ and ϵ	Oct. 17

Eleven cases, therefore, are furnished for examination, and of these the spots 313 η and 316 ψ have no life histories recorded in Mr. Howlett's drawings, and hence it is impossible to say whether they should be admitted as test cases. A reference to the Stonyhurst drawings of these groups is against their admission, on account of their disturbed nature. The spot 314 σ, too, showed great changes between May 17 and 18, as can be seen from the sheet 315, and must be excluded from the discussion. Spot 317 u must also be rejected on account of the disturbances registered on June 3 and 4. The spot 320 ξ in the enlarged drawing made at 7.30 A.M. on July 18 is seen to be of a broken outline with bright patches in the penumbra ; and on the 21st, when nearly central, shows penumbra on one side only, and that the inner side from the Sun's centre. The next spot, 321 β, underwent a period of disturbance between June 25 and 29. With regard to 329 ω it is depicted as a black line nearly on the limb, but so hazy and ill-defined that it is impossible to determine whether it be composed of umbra or penumbra. There is no

enlarged drawing of the spot on the previous day, but on August 26 an enormous extent of faculæ is recorded on the preceding limb. From the drawings, too, it would appear that this spot is identical with the spot ϵ of August 23 and 26; and if so, between these two dates the umbra had separated into three parts, with a great change in the penumbra. The spots 330 ι and ζ must likewise be rejected as being disturbed spots, and moreover in the case of the first the umbra was not centrally placed with regard to the penumbra. As to the disturbed nature of the spots, the evidence furnished by the drawings with regard to the first is that on September 8, at 4.30 P.M., it had two nuclei which had coalesced into one by 8 A.M. the next morning; while with regard to the latter its nucleus on September 3 was long and compact; on September 4 it showed evident signs of breaking up; and when on the limb on September 8 the S. part of the spot was composed of penumbra which corresponded to the penumbral tail of September 3 and 4. Of the group 335 δ and ϵ the latter spot was of irregular outline, with scattered umbra and penumbra on October 13, and two days after a portion on the preceding side was detached from it. Again on October 17 there was much faculæ near the limb, and, as Secchi has pointed out, the presence of faculæ in the region of a spot frequently counteracts the appearance it would present were it a cavity; and moreover in this case the spot, if admitted at all, would seem to tell rather for than against the depression hypothesis. There remains the group 335 δ, which on October 13 consisted of four spots, two of them—and these the more northerly—being irregular and disturbed, and two being of more constant outline. Of these two again one had not the umbra central on October 13, but the penumbra was much more extensive on the inner side than on the outer side, and hence when foreshortened apparently told against Wilson's view. There remains but one spot to be dealt with, and that is the most southerly of the whole group. On October 13 the umbra extended rather in the E. and W. direction, the penumbra being more extensive on the N. than on the S. of the spot. On October 15 the umbra is represented as lying more in the N. and S. direction, as if the spot had partly turned on its axis. On October 17 the penumbra is about equal on each side of the umbra, instead of being less on the inner side, and so far is against Wilson.

From this discussion of the individual cases quoted it would appear that the witness of all these spots, with one possible exception, must be rejected. The study of these cases was made from Mr. Howlett's drawings, without any reference to, or help from, other drawings or photographs, so as to avoid all bias and prejudice. Subsequently, however, all the above spots were studied on the Stonyhurst drawings, with the exception of 329 ω, and of part of the group 330 ι and ζ, of which we have no record. In every case the description of the spots given above is fully

corroborated, and the only spot which can possibly tell against the Wilsonian hypothesis is the most southerly member of the group 335, which on October 17 was about 25″ of arc from the preceding limb of the Sun. The evidence of this one spot is reliable, but by no means weighty, as adverse to the depression hypothesis.

Among the cases of Sun-spots indexed by Mr. Howlett (vol. vii.) as "decidedly adverse to Wilson" are two dated 1887 July 4 and July 6. The evidence of the Stonyhurst drawings with reference to these examples can be studied in Plate 7 of the *Memoirs R.A.S.* vol. xlix. p. 286, illustrating Father Perry's paper on "Photographs and Drawings of the Sun." Group 4 of the plate corresponds to Mr. Howlett's first case, and it will be seen on reference to the series of reproductions of the drawings, which are somewhat smaller in size than the originals, that on July 3–4, when the spot is near the following solar limb, the evidence is apparently against Wilson, but on the 14th, when near the preceding limb, it is much more strongly, seemingly, in his favour. But it will be noticed that the evidence is weakened by the drawing on the 13th, and from the shifting of and changes in the umbra from day to day as the spot crossed the limb. If the spot is to be regarded as a test case, then as far as the Stonyhurst drawings bear witness it cannot be said to be "decidedly against Wilson," but rather in his favour. This case was rejected as unreliable in the discussion of the bearing of the Stonyhurst series of drawings on the Wilsonian hypothesis. With regard to the spot dated 1887 July 6, group 3 of the plate shows a spot which is in favour of the depression theory when on the preceding limb, and this cannot be the spot referred to. But in group 5 we can study two normal spots as they cross the disc, and of these the first is against Wilson's theory on the 6th, but again for the theory when on the preceding limb on the 17th; while the second one, though a small spot, is against Wilson both on the 6th and 17th. The reproduction of the 18th is not quite correct; the original is against Wilson. Hence it appears that the Stonyhurst drawings bear out Mr. Howlett's contention in one of his two "decided" cases, and that only partially. But there is one set of drawings—those, namely, which constitute group 2 of the same plate—which is a very strong case against the Wilsonian view. Father Sidgreaves has already called attention to this example, in his paper before referred to, as indicating rather a mountainous than a cavernous form of umbra in the spot.

It would appear, then, from this detailed examination of some of the cases adduced by Mr. Howlett that their evidence is by no means conclusive against the Wilsonian theory. On the other hand it must be admitted that the phenomena presented by many spots are directly contrary to the theory, and from a careful study of these on the Stonyhurst drawings Father Sidgreaves has been led (*loc. cit.*, p. 286) to a partial confirmation of Mr. Howlett's adverse criticism. To the writer it seems, without contesting in

any way or expressing any opinion upon the theory advocated in opposition to the depression hypothesis of Sun-spots, that the strength of the position taken up by Mr. Howlett is not warranted by his drawings, and that the weight of the negative evidence derived from them must be modified.

Stonyhurst College Observatory:
1898 *January* 14.

Observations of Occultations of Stars by the Moon and of Phenomena of Jupiter's Satellites made at the Royal Observatory, Greenwich, in the year 1897.

(*Communicated by the Astronomer Royal.*)

Day	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Apr. 15	Disapp. W.B. XII. 334	Astrographic Equat.	225	Dark	11 32 38·24	J.
May 4	Reapp. Piazzi IV. 287	Altazimuth	100	Bright	8 38 0·98	H.
4	Disapp. W.B. (2) IV. 1358–9	"	100	Dark	8 39 49·58	"
6	" W.B. (2) VI. 1452	"	100	"	9 36 31·67	A. C.
6	" W.B. (2) VI. 1447	Sheepshanks Equat.	100	"	9 38 30·78	J.
June 18	" Piazzi XXI. 291	"	100	Bright	13 42 37·24	S.
18	Reapp. "	"	100	Dark	14 10 47·50	"
July 11 (*a*)	" Lalande 31226	Astrographic Equat.	225	Bright	9 6 41·95	W.
13	Disapp. χ^1 Sagittarii	Sheepshanks Equat.	55	Dark	9 21 4·17	B.
13	" "	Altazimuth	100	"	9 21 4·27	S.
13	" "	Astrographic Equat.	225	"	9 21 3·87	W. S.
13 (*b*)	Reapp. "	Sheepshanks Equat.	225	Bright	10 22 (10·20)	B.
13	" "	Altazimuth	100	"	10 22 7·82	S.
23	Disapp 17 Tauri	Astrographic Equat.	225		12 17 2·78	C. D.
23	" "	Sheepshanks Equat.	100	"	12 17 (0·09)	W. S.
23	" 16 Tauri	Astrographic Equat.	120	"	12 40 35·43	C. D.
23	Reapp. "	"	120	Dark	12 53 29·52	"

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
July 23	Reapp. 16 Tauri	Sheepshanks Equat.	100	Dark	12 53 29·89	W. S.
23	Disapp. 23 Tauri	Astrographic Equat.	120	Bright	12 55 15·53	C. D.
23	,, ,,	Sheepshanks Equat.	100	,,	12 55 14·80	W. S.
23 (a)	,, Piazzi III. 135	Astrographic Equat.	225	,,	12 58 53·44	C. D.
23 (a)	,, B.D. + 23° No. 523	,,	225	,,	13 1 9·07	,,
23	Reapp. 17 Tauri	,,	120	Dark	13 10 4·51	,,
23	,, ,,	Corbett Tel.	100	,,	13 10 3·72	H. F.
23	,, ,,	28-inch Equat.	670	,,	13 10 3·52	S.
23	,, W.B. (2) III. 812	Astrographic Equat.	120	,,	13 10 57·47	C. D.
23	,, Piazzi III. 135	,,	120	,,	13 19 24·29	,,
23	,, ,,	Sheepshanks Equat.	100	,,	13 19 (25·83)	W. S.
23	,, B.D. + 23° No. 510	Astrographic Equat.	120	,,	13 22 13·63	C. D.
23	Disapp. η Tauri	,,	120	Bright	13 22 45·74	,,
23	,, ,,	Corbett Tel.	100	,,	13 22 46·41	H. F.
23	,, ,,	28-inch Equat.	670	,,	13 22 46·41	S.
23	,, ,,	Sheepshanks Equat.	100	,,	13 22 46·28	W. S.
23	,, Piazzi III. 151	Corbett Tel.	100	,,	13 26 46·13	H. F.
23	,, ,,	28-inch Equat.	670	,,	13 26 46·73	S.
23	Reapp. B.D. + 23° No. 513	Astrographic Equat.	225	Dark	13 28 36·58	C. D.
23	,, B.D. + 23° No. 517	,,	120	,,	13 32 30·95	,,

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
July 23	Reapp. 23 Tauri	Corbett Tel.	100	Dark	13 32 29·37	H. F.
23	" "	28-inch Equat.	670	"	13 32 29·17	S.
23	" W.B. (2) III. 845	Corbett Tel.	100	"	13 47 51·60	H. F.
23	" "	28-inch Equat.	670	"	13 47 51·20	S.
23	" W.B. (2) III. 846	Astrographic Equat.	120	"	13 48 51·36	C. D.
23	" "	Corbett Tel.	100	"	13 48 51·32	H. F.
23	" "	28-inch Equat.	670	"	13 48 50·82	S.
23	" "	Sheepshanks Equat.	100	"	13 48 (52·47)	W. S.
23	" B.D. + 23° No. 528	Astrographic Equat.	120	"	13 52 34·76	C. D.
23	" "	Corbett Tel.	100	"	13 52 35·21	H. F.
23	" "	Sheepshanks Equat.	100	"	13 52 34·36	W. S.
23	" B.D. + 23° No. 523	Astrographic Equat.	120	"	13 54 15·68	C. D.
23	" "	Corbett Tel.	100	"	13 54 15·62	H. F.
23	" "	28-inch Equat.	670	"	13 54 14·62	S.
23	" B.D. + 23° No. 526	Astrographic Equat.	120	"	13 55 40·15	C. D.
23	" B.D + 23° No. 531	"	120	"	14 12 17·44	"
23	" "	Corbett Tel.	100	"	14 12 16·61	H. F.
23	" "	Sheepshanks Equat.	100	"	14 12 17·11	W. S.
23	" 24 Tauri	Astrographic Equat.	120	"	14 13 4·31	C. D.
23	" "	Corbett Tel.	100	"	14 13 3·57	H. F.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
July 23	Reapp. 24 Tauri	28-inch Equat.	670	Dark	14 13 4·87	S.
23	„ „	Sheepshanks Equat.	100	„	14 13 3·98	W. S.
23	„ B.D. + 23° No. 534	Astrographic Equat.	120	„	14 14 14·03	C. D.
23 (c)	„ „	Corbett Tel.	100	„	14 14 (16·59)	H. F.
23	„ η Tauri	Astrographic Equat.	120	„	14 15 3·98	C. D.
23	„ „	Corbett Tel.	100	„	14 15 3·04	H. F.
23	„ „	28-inch Equat.	670	„	14 15 2·44	S.
23	„ „	Sheepshanks Equat.	100	„	14 15 3·65	W. S.
23	Disapp. 28 Tauri	Astrographic Equat.	120	Bright	14 17 22·40	C. D.
23 (a)	„ „	Corbett Tel.	100	„	14 17 (19·45)	H. F.
23	„ „	28-inch Equat.	670	„	14 17 21·55	S.
23	Reapp. Piazzi III. 151	Astrographic Equat.	120	Dark	14 24 50·29	C. D.
23	„ „	Corbett Tel.	100	„	14 24 49·81	H. F.
23	„ „	28-inch Equat.	670	„	14 24 49·81	S.
23	„ „	Sheepshanks Equat.	100	„	14 24 49·75	W. S.
23	„ B.D. + 23° No. 548	Astrographic Equat.	120	„	14 32 59·85	C. D.
23 (a)	Disapp. Piazzi III. 164	Corbett Tel.	100	Bright	14 33 17·59	H. F.
23	„ „	28-inch Equat.	670	„	14 33 18·29	S.
23	Reapp. B.D. + 23° No. 549	Astrographic Equat.	120	Dark	14 46 44·31	C. D.
23	„ „	Corbett Tel.	100	„	14 46 45·85	H. F.
23	„ „	28-inch Equat.	670	„	14 46 45·35	S.
23	„ B.D. + 23 No. 554	Astrographic Equat.	120	„	14 47 31·78	C. D.
	„ „	Corbett Tel.	100	„	14 47 31·81	H. F.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
July 23	Reapp. B.D. + 23 No. 554	28-inch Equat.	670	Dark	14 47 31·71	S.
23	" 28 Tauri	Astrographic Equat.	120	"	14 52 45 13	C. D.
23	" "	Corbett Tel.	100	"	14 52 44·84	H. F.
23	" "	28-inch Equat.	670	"	14 52 44·84	S.
23	" Bradley 523	Corbett Tel.	100	"	14 55 35·36	H. F.
23	" "	28-inch Equat.	670	"	14 55 33·86	S.
23	" B.D. + 23° No. 562	Astrographic Equat.	120	"	15 14 26·19	C. D.
23	" "	Corbett Tel.	100	"	15 14 25·52	H. F.
23	" "	28-inch Equat.	670	"	15 14 24·32	S.
23	" "	Sheepshanks Equat.	100	"	15 14 24·90	W. S.
23	" B.D. + 23° No. 560	Astrographic Equat.	120	"	15 19 52·20	C. D.
23	" "	Corbett Tel.	100	"	15 19 51·20	H. F.
23	" "	28-inch Equat.	670	"	15 19 50·80	S.
23	" W.B. (2) III. 903	Astrographic Equat.	120	"	15 21 53·57	C. D.
23	" "	Corbett Tel.	100	"	15 21 52·47	H. F.
23	" "	28-inch Equat.	670	"	15 21 52·17	S.
23	" "	Sheepshanks Equat.	100	"	15 21 53·46	W. S.
23 (*d*)	" Piazzi III. 164	Corbett Tel.	100	"	15 36 36·80	H. F.
23	" "	28-inch Equat.	670	"	15 36 36·00	S.
Aug. 4	Disapp. 89 Virginis	Altazimuth	100	"	8 17 0·81	H.
Oct. 3	" χ^2 Sagittarii	Sheepshanks Equat.	125	"	6 41 59·42	W.
3	" χ^1 Sagittarii	Astrographic Equat.	225	"	6 42 59·57	R. C.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Oct. 3	Disapp. χ^1 Sagittarii	Sheepshanks Equat.	125	Dark	6 42 59·35	W.
3	Reapp. "	"	125	Bright	7 33 59·57	"

Notes.

(*a*) Not considered a good observation.
(*b*) Seemed to be a slight distance from limb when first seen.
(*c*) The observer noted that the observed time was probably late.
(*d*) Observed in twilight. The observed time has been diminished by one minute.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time of *N.A.* h m	Observer.
1897. Jan. 27	I. (*a*)	Tr. Ing. First contact	E. Equat.	120	9 6 56·41		H.
27	I.	Bisection	"	"	9 9 1·07	9 10	"
27	I.	Last contact	"	"	9 11 15·7		"
27	I.	Tr. Egr. Bisection	"	"	11 28 13·34	11 29	"
27	I.	Last contact	"	"	11 30 8·03		"
28	II.	Tr. Ing. Bisection	"	"	9 53 48·53	9 55	A. C.
28	II.	Last contact	"	"	9 55 33·24		
28	II.	Tr. Egr. First contact	"	"	12 38 37·58		"
28	II.	Bisection	"	"	12 40 43·24	12 45	"
28	II.	Last contact	"	"	12 42 23·96		"
Mar. 13	I. (*b*)	Occ. D. First contact	"	"	11 7 45·23		W. B.
13	I.	Bisection	"	"	11 9 10·00	11 9	"
13	I.	Last seen	"	"	11 10 24·80		"

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of N.A.	Observer.
					h m s	h m s	
Mar. 22	I.	Ecl. R. First seen	Transit Circle	195	10 15 0·81	10 14 55	H. F.
22	I.	Bisection	"	"	10 16 5·62		"
30	I. (c)	Sh. Egr. First contact	Astrog. Equat.	225	9 27 17·68	9 32	C. D.
30	I.	Last contact	"	"	9 31 12·03		
30	III.	Tr. Ing. First contact	"	"	9 41 55·27		"
30	III.	Bisection	"	"	9 45 9·74	9 44	"
30	III.	Last contact	"	"	9 49 58·96		"
Apr. 14	I.	Ecl. R. Full brightness	E. Equat.	200	10 29 8·01	10 27 33	H.
18	II.	Ecl. R. First seen	Astrog. Equat.	225	11 0 46·31	11 0 24	H. F.
18	II.	Bisection	"	"	11 2 6·08		"
18	II.	Full brightness	"	"	11 4 0·77		"
28	I.	Occ. D. Bisection	E. Equat.	120	10 50 13·36	10 50	B.
28	I.	Last seen	"	"	10 51 33·13		
May 20	II.	Ecl. R. First seen	"	"	10 40 37·06	10 39 38	W.
20	II.	Bisection	"	"	10 41 56·84		"
20	II.	Full brightness	"	"	10 43 56·51		"

Notes.

(a) Bad definition. (b) Thin cloud over *Jupiter*. (c) Definition very poor.

The initials H., A. C., B., C. D., W. B., H. F., R. C., J., S., W., W. S., are those of Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Davidson, Mr. Bowyer, Mr. Furner, Mr. Cheeseman, Mr. Johns, Mr. Showell, Mr. Witchell, and Mr. Stevens respectively.

Occultations of the Pleiades by the Moon on 1897 July 23 and 1898 January 3, observed at the Radcliffe Observatory, Oxford.

(*Communicated by the Radcliffe Observer.*)

The following are observations of two occultations of the Pleiades by the Moon, viz. on 1897 July 23 and 1898 January 3:—

	Name of Star.	Magnitude.	Phenomenon.	Moon's Limb.	Observer.	Instrument.	Power.	Time Noted.	Oxford Sidereal Time.	Greenwich Mean Time.	Ref. No.
								h m s	h m s	h m s	
1897. July 23	17 Tauri	3·8	Disapp.	Bright	R.	Barclay Equat.	85	20 18 45·5	20 21 3·12	12 18 8·5	(1)
	16 Tauri	6·5	Reapp.	Dark	R.	„	85	20 51 36·0	20 53 53·74	12 50 53·8	(2)
	17 Tauri	3·8	„	„	R.	„	45	21 11 24·9	21 13 42·71	13 10 39·5	...
	Arg. Z + 23°·536	6·8*	Disapp.	Bright	R.	„	45	21 19 48·	21 22 5·84	13 19 1·2	(3)
	η Tauri	3·0	„	„	R.	„	45	21 23 57·7	21 26 15·54	13 23 10·3	(4)
	Arg. Z + 23°·540	7·0*	„	„	R.	„	45	21 28 25·	21 30 42·86	13 27 36·8	(5)
	Arg. Z + 23°·517	8·0*	Reapp.	Dark	R.	„	45	21 33 52·	21 36 30·72	13 33 23·8	(6)
	23 Tauri	4·2	„	„	R.	„	45	21 34 26·7	21 37 5·42	13 33 58·4	(7)
	Arg. Z + 23°·536	6·8*	„	„	R.	„	45	22 13 37·3	22 16 16·15	14 13 2·7	...
	η Tauri	3·0	„	„	R.	„	45	22 14 28·0	22 17 6·85	14 13 53·2	(8)
	28 Tauri	6·2	Disapp.	Bright	R.	„	45	22 17 6·	22 19 44·86	14 16 30·8	(9)
	28 Tauri	6·2	Reapp.	Dark	R.	„	45	22 54 59·5	22 57 38·50	14 54 18·2	(10)
1898. Jan. 3	17 Tauri	3·8	Disapp.	Dark	W.	Heliometer	80	2 1 29·2	2 1 15·32	7 12 35·8	(11)

	Name of Star.	Magnitude.	Phenomenon.	Moon's Limb.	Observer.	Instrument.	Power.	Time Noted.	Oxford Sidereal Time.	Greenwich Mean Time.	Ref. No.
1898.								h m s	h m s	h m s	
Jan. 3	17 Tauri	3·8	Disapp.	Dark	R.	Barclay Eq.	85	2 1 29·0	2 1 15·24	7 12 35·7	(12)
	Arg. Z + 23°·510	8·1*	,,	,,	W.	Heliometer	80	2 12 58·3	2 12 44·41	7 24 3·0	(13)
	,,	,,	,,	,,	R.	Barclay Eq.	85	2 12 58·0	2 12 44·27	7 24 2·8	(14)
	Arg. Z + 23° 517	8·0*	,,	,,	W.	Heliometer	80	2 28 30·2	2 28 16·31	7 39 32·3	(15)
	,,	,,	,,	,,	R.	Barclay Eq.	85	2 28 29·8	2 28 16·13	7 39 32·2	(16)
	23 Tauri	4·2	,,	,,	W.	Heliometer	80	2 47 52·8	2 47 38·89	7 58 51·7	(17)
	,,	,,	,,	,,	R.	Barclay Eq.	85	2 47 52·5	2 47 38·88	7 58 51·7	(18)
	Arg. Z + 23°·519	8·2*	,,	,,	W.	Heliometer	80	2 53 1·2	2 52 47·28	8 3 59·3	...
	,,	,,	,,	,,	R.	Barclay Eq.	85	2 53 0·0	2 52 46·39	8 3 58·4	(19)
	Arg. Z + 23°·520	8·4*	,,	,,	W.	Heliometer	80	2 53 30·5	2 53 16·58	8 4 28·5	...
	,,	,,	,,	,,	R.	Barclay Eq.	85	2 53 30·5	2 53 16·89	8 4 28·8	(20)
	Arg. Z + 23°·523	7·4*	,,	,,	R.	,,	85	3 8 26·4	3 8 12·83	8 19 22·3	(21)
	17 Tauri	3·8	Reapp.	Bright	W.	Heliometer	80	3 14 25·	3 14 11·07	8 25 19·6	(22)
	Arg. Z + 23°·536	6·8*	Disapp.	Dark	R.	Barclay Eq.	85	3 27 5·0	3 26 51·49	8 37 57·9	(23)
	η Tauri	3·0	,,	,,	W.	Heliometer	80	3 32 8·2	3 31 54·25	8 42 59·8	(24)
	,,	,,	,,	,,	R.	Barclay Eq.	85	3 32 6·75	3 31 53·26	8 42 58·9	(25)
	23 Tauri	4·2	Reapp.	Bright	W.	Heliometer	80	3 59 7·	3 58 53·02	9 9 54·2	...
	28 Tauri	6·2	Disapp.	Dark	W.	,,	80	4 40 48·0	4 40 34·00	9 51 28·4	...

1898.	Name of Star.	Magnitude.	Phenomenon.	Moon's Limb.	Observer.	Instrument.	Power.	Time Noted.	Oxford Sidereal Time.	Greenwich Mean Time.	Ref. No.
								h m s	h m s	h m s	
Jan. 3	28 Tauri	6·2	Disapp.	Dark	R.	Barclay Eq.	85	4 40 47·3	4 40 34·01	9 51 28·4	(26)
	27 Tauri	3·8	„	„	W.	Heliometer	80	4 46 8·15	4 45 54·14	9 56 47·6	(27)
	„	„	„	„	R.	Barclay Eq.	45	4 46 7·15	4 45 53·87	9 56 47·4	...
	η Tauri	3·0	Reapp.	Bright	W.	Heliometer	80	4 55 43·5	4 55 29·48	10 6 21·4	(28)
	„	„	„	„	R.	Barclay Eq.	45	4 55 39·	4 55 25·75	10 6 17·7	(29)

The magnitudes given above are taken from the *N.A.*, or when marked with an asterisk from the Berlin (B) A.G. Catalogue.

Observers' Remarks.

(1) Gradual disappearance. (2) Instantaneous. (3) Merest speck at disappearance. (4) Good. (5) Faint. (6) Angle from vertex about 280°. (7), (8) Instantaneous. (9) Gradual disappearance. (10), (11) Instantaneous. (12) Good; instantaneous. (13), (15) In the same parallel and of nearly equal magnitude. (14), (16) Good; instantaneous. (17) Good. (18) Instantaneous; fairly good. (19) Fairly good; colour reddish. (20) Fairly good; magnitude estimated 0·2 fainter than (19). (21) Good. (22) May be a second late, not more. (23) Good; instantaneous. (24) Instrument had just been moved in R.A. to correct the diurnal movement when disappearance occurred. (25), (26) Good; instantaneous. (27), (28) Good. (29) Good; image of star very small; thin film of frost on object glass.

A ground fog prevailed during the occultations of 1898 January 3, and was at times rather dense.

The Barclay Equatorial is situated $0^s{\cdot}4$ west of the heliometer.

Observers:—W., Mr. W. Wickham; R., Mr. W. H. Robinson.

Radcliffe Observatory, Oxford:
1898 *January* 10.

Ephemeris for Physical observations of

(Continued from

Greenwich Noon.	P	L−O	B	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d	ω	B′
1898.	°	°	°	″	″	″	°	°	°
Mar. 2	25·041	52·726	−2·697	44·07	0·07	41·30	4·62	264·8	−2·88
4	25·057	52·514	2·695	44·20	·06	41·43	4·26	264·4	2·87
6	25·073	52·294	2·693	44·32	·05	41·55	3·89	263·9	2·87
8	25·089	52·067	2·690	44·43	·04	41·65	3·51	263·3	2·87
10	25·105	51·834	2·687	44·54	·03	41·75	3·13	262·5	2·87
12	25·122	51·595	2·683	44·64	·02	41·84	2·74	261·6	2·86
14	25·139	51·350	2·678	44·72	·02	41·92	2·35	260·7	2·86
16	25·156	51·102	2·673	44·78	·01	41·98	1·96	259·1	2·85
18	25·172	50·851	2·667	44·84	·01	42·03	1·56	256·5	2·85
20	25·188	50·596	2·661	44·88	·00	42·07	1·17	252·7	2·84
22	25·203	50·339	2·654	44·92	·00	42·11	0·79	245	2·83
24	25·218	50·081	2·647	44·95	·00	42·13	0·43	224	2·82
26	25·233	49·823	2·639	44·95	·00	42·13	0·30	163	2·82
28	25·247	49·564	2·631	44·95	·00	42·13	0·58	120	2·81
30	25·261	49·307	2·622	44·92	·00	42·11	0·97	106 6	2·80
Apr. 1	25·274	49·052	−2·613	44·89	0·01	42·08	1·35	101·2	−2·79
3	25·287	48·798	2·604	44·85	·01	42·04	1·74	98·2	2·78
5	25·299	48·548	2·594	44·80	·02	42·00	2·14	96·1	2·77
7	25·311	48·301	2·583	44·74	·02	41·94	2·53	94·7	2·76
9	25·322	48·059	2·572	44·66	·03	41·86	2·92	93·80	2·75
11	25·332	47·822	2·561	44·58	·04	41·78	3·31	92·99	2·73
13	25·341	47·590	2·550	44·47	·05	41·69	3·69	92·35	2·72
15	25·350	47·364	2·539	44·36	·06	41·58	4·06	91·86	2·71
17	25·359	47·146	2·528	44·25	·07	41·48	4·44	91·50	2·70
19	25·367	46·937	2·517	44·12	·08	41·35	4·79	91·20	2·68
21	25·374	46·733	2·505	43·97	·09	41·22	5·15	90·95	2·67
23	25·381	46·537	2·493	43·82	·10	41·07	5·50	90·71	2·66
25	25·387	46·351	2·481	43·67	·11	40·94	5·83	90·50	2·65
27	25·392	46·174	2·469	43·50	·13	40·78	6·16	90·31	2·63
29	25·397	46·007	2·457	43·33	·14	40·61	6·48	90·14	2·62
May 1	25·402	45·851	−2·445	43·15	0·15	40·45	6·79	89·99	−2·61
3	25·406	45·705	2·434	42·96	·16	40·27	7·08	89·85	2·60
5	25·410	45·570	2·423	42·77	·17	40·09	7·37	89·72	2·58
7	25·413	45·446	2·412	42·57	·19	39·90	7·64	89·59	2·57
9	25·416	45·333	−2·401	42·36	0·20	39·71	7·91	89·47	−2·56

Jupiter, 1898. By A. C. D. Crommelin.

page 31.)

Greenwich Noon. 1898.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time	A−O	B
	°	°	°	m	°	°
Mar. 2	140·13	226·80	+0·09	37·80	48·108	−2·286
4	96·20	167·62	·08	37·69	48·259	2·292
6	52·29	108·44	·07	37·58	48·410	2·297
8	8·37	49·26	·05	37·49	48·560	2·302
10	324·47	350·10	·04	37·39	48·711	2·308
12	280·55	290·92	·03	37·32	48·863	2·313
14	236·64	231·75	·02	37·25	49·014	2·318
16	192·72	172·57	·02	37·19	49·165	2·324
18	148·80	113·39	+0·01	37·14	49·316	2·329
20	104·88	54·20	·00	37·11	49·467	2·334
22	60·95	355·02	·00	37·08	49·617	2·340
24	17·02	295·83	·00	37·06	49·769	2·345
26	333·08	236·63	·00	37·06	49·920	2·350
28	289·14	177·43	·00	37·06	50·071	2·356
30	245·18	118·21	·00	37·08	50·222	2·361
Apr. 1	201·23	58·99	·00	37·10	50·373	−2·366
3	157·26	359·77	−0·01	37·13	50·524	2·371
5	113·28	300·53	·02	37·18	50·675	2·376
7	69·30	241·29	·03	37·23	50·826	2·381
9	25·30	182·03	·04	37·30	50·977	2·386
11	341·29	122·76	·05	37·37	51·128	2·391
13	297·27	63·48	·06	37·46	51·279	2·396
15	253·24	4·19	·07	37·55	51·430	2·401
17	209·20	304·90	·09	37·64	51·581	2·406
19	165·14	245·57	·10	37·76	51·731	2·411
21	121·07	186·24	·12	37·88	51·882	2·416
23	76·99	126·90	·13	38·01	52·033	2·421
25	32·89	67·55	·15	38·14	52·184	2·426
27	348·78	8·17	·17	38·29	52·336	2·431
29	304·65	308·79	·18	38·44	52·487	2·436
May 1	260·51	249·39	−0·20	38·60	52·638	−2·440
3	216·35	189·97	·22	38·77	52·788	2·445
5	172·18	130·54	·24	38·95	52·939	2·450
7	127·99	71·09	·26	39·13	53·090	2·455
9	83·79	11·63	−0·28	39·32	53·241	−2·460

Greenwich Noon.	P	L−O	B	Apparent Diameter. Equat. 2a.	Defect.	Polar 2b.	d	ω	B′
1898.	°	°	°	″	″	″	°	°	°
May 11	25·418	45·231	−2·390	42·15	0·21	39·52	8·16	89·36	−2·55
13	25·420	45·141	2·379	41·94	·22	39·31	8·40	89·27	2·54
15	25·422	45·063	2·368	41·73	·23	39·11	8·63	89·18	2·53
17	25·424	44·996	2·358	41·51	·25	38·90	8·85	89·09	2·52
19	25·425	44·942	2·348	41·28	·26	38·70	9·05	89·01	2·51
21	25·426	44·898	2·339	41·06	·27	38·49	9·25	88·94	2·50
23	25·426	44·867	2·330	40·83	·28	38·27	9·43	88·88	2·49
25	25·427	44·849	2·321	40·60	·29	38·06	9·60	88·81	2·48
27	25·427	44·842	2·312	40·36	·29	37·83	9·76	88·74	2·47
29	25·426	44·848	2·304	40·13	·30	37·62	9·90	88·67	2·46
31	25·426	44·866	2·296	39·90	·30	37·40	10·04	88·60	2·45
June 2	25·425	44·897	−2·289	39·67	0·31	37·19	10·16	88·54	−2·44
4	25·424	44·939	2·282	39·44	·31	36·96	10·26	88·48	2·43
6	25·423	44·993	2·276	39·21	·32	36·75	10·36	88·42	2·43
8	25·421	45·058	2·270	38·97	·32	36·54	10·45	88·37	2·42
10	25·419	45·135	2·264	38·75	·33	36·32	10·52	88·32	2·41
12	25·417	45·223	2·259	38·52	·33	36·11	10·59	88·28	2·41
14	25·414	45·322	2·254	38·29	·33	35·89	10·64	88·23	2·40
16	25·411	45·433	2·250	38·07	·33	35·69	10·68	88·19	2·40
18	25·408	45·554	2·246	37·84	·33	35·47	10·71	88·14	2·40
20	25·405	45·686	2·242	37·62	·33	35·26	10·73	88·09	2·39
22	25·401	45·829	2·239	37·40	·33	35·06	10·73	88·04	2·39
24	25·397	45·983	2·236	37·19	·32	34·85	10·73	88·00	2·39
26	25·392	46·147	2·234	36·97	·32	34·65	10·72	87·96	2·38
28	25·387	46·321	2·233	36·76	·32	34·45	10·69	87·92	2·38
30	25·381	46·504	2·232	36·55	·32	34·26	10·66	87·88	2·38
July 2	25·374	46·698	−2·231	36·35	0·31	34·07	10·62	87·85	−2·38
4	25·367	46·901	2·230	36·15	·31	33·88	10·57	87·81	2·38
6	25·359	47·113	2·229	35·95	·30	33·70	10·50	87·78	2·38
8	25·350	47·335	2·230	35·75	·30	33·51	10·43	87·74	2·38
10	25·341	47·565	2·231	35·56	·29	33·33	10·36	87·71	2·38
12	25·332	47·803	2·232	35·38	·28	33·16	10·27	87·67	2·38
14	25·322	48·050	2·233	35·19	·28	32·98	10·17	87·64	2·38
16	25·311	48·306	2·235	35·01	·27	32·82	10·07	87·60	2·38
18	25·299	48·569	2·237	34·83	·26	32·65	9·95	87·56	2·39
20	25·286	48·840	2·240	34·65	·25	32·49	9·83	87·52	2·39
22	25·273	49·119	2·243	34·49	·25	32·33	9·71	87·48	2·39
24	25·259	49·406	−2·246	34·33	0·24	32·18	9·57	87·44	−2·40

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870°·27 II.	Corr. for Phase.	Light-time.	A−O	R
1898.	°	°	°	m	°	°
May 11	39·58	312·16	− 0·30	39·51	53·392	−2·465
13	355·34	252·66	·32	39·72	53·543	2·470
15	311·10	193·16	·33	39·92	53·694	2·474
17	266·84	133·64	·35	40·13	53·843	2·479
19	222·56	74·11	·36	40·34	53·995	2·484
21	178·27	14·55	·37	40·57	54·146	2·489
23	133·96	314·99	·38	40·79	54·297	2·493
25	89·63	255·40	·40	41·03	54·448	2·498
27	45·30	195·81	·41	41·26	54·599	2·503
29	0·94	136·19	·42	41·51	54·751	2·507
31	316·58	76·58	·44	41·74	54·902	2·512
June 2	272·20	16·93	−0·45	41·99	55·053	−2·516
4	227·81	317·28	·46	42·24	55·203	2·521
6	183·41	257·62	·47	42·48	55·354	2·525
8	138·98	197·94	·48	42·74	55·505	2·530
10	94·55	138·25	·48	42·99	55·656	2·534
12	50·11	78·55	·49	43·24	55·807	2·539
14	5·66	18·84	·49	43·50	55·958	2·543
16	321·19	319·12	·50	43·75	56·109	2·548
18	276·71	259·37	·50	44·02	56·260	2·553
20	232·22	199·62	·50	44·28	56·411	2·557
22	187·71	139·86	·50	44·54	56·562	2·562
24	143·21	80·10	·50	44·79	56·712	2·566
26	98·68	20·32	·50	45·05	56·863	2·571
28	54·15	320·52	·50	45·31	57·014	2·575
30	9·61	260·72	·50	45·57	57·165	2·580
July 2	325·06	200·92	−0·49	45·82	57·316	−2·584
4	280·50	141·10	·49	46·08	57·467	2·588
6	235·94	81·28	·48	46·33	57·618	2·592
8	191·36	21·44	·48	46·59	57·769	2·597
10	146·78	321·59	·47	46·84	57·920	2·601
12	102·18	261·75	·46	47·09	58·071	2·605
14	57·59	201·89	·45	47·34	58·222	2·610
16	12·99	142·03	·44	47·57	58·372	2·614
18	328·37	82·16	·43	47·82	58·523	2·618
20	283·76	22·28	·42	48·06	58·674	2·623
22	239·13	322·40	·41	48·30	58·825	2·627
24	194·50	262·51	−0·40	48·53	58·977	−2·631

Greenwich Noon.	P	L−O	B	Apparent Diameter. Equat. 2*a*.	Defect.	Polar 2*b*.	*d*	*ϖ*	B′
1898.	°	°	°	″	″	″	°	°	°
July 26	25·243	49·700	−2·250	34·17	0·23	32·03	9·43	87·41	−2·40
28	25·226	50·001	2·254	34·01	·22	31·88	9·28	87·37	2·40
30	25·208	50·308	2·258	33·85	·21	31·74	9·12	87·32	2·41
Aug. 1	25·189	50·624	−2·263	33·71	0·20	31·59	8·96	87·27	−2·41
3	25·169	50·944	2·268	33·56	·19	31·46	8·79	87·22	2·42
5	25·149	51·271	2·273	33·42	·18	31·32	8·61	87·17	2·42
7	25·127	51·604	2·278	33·28	·18	31·20	8·43	87·13	2·43
9	25·104	51·943	2·284	33·15	·17	31·08	8·24	87·08	2·44
11	25·079	52·287	2·290	33·02	·16	30·95	8·05	87·03	2·44
13	25·053	52·636	2·297	32·90	·16	30·83	7·85	86·99	2·45
15	25·026	52·992	2·304	32·77	·15	30·72	7·65	86·94	2·46
17	24·997	53·353	−2·312	32·66	0·14	30·61	7·44	86·89	−2·47

Greenwich Noon.	Longitude of ♃'s Central Meridian. 877°·90 I.	870° 27 II.	Corr. for Phase.	Light-time	A−O	*B*
1898.	°	°	°	m	°	°
July 26	149·88	202·63	−0·38	48·75	59·128	−2·635
28	105·24	142·73	·37	48·98	59·279	2·639
30	60·59	82·83	·36	49·20	59·430	2·644
Aug. 1	15·94	22·92	−0·35	49·42	59·581	−2·648
3	331·29	323·00	·34	49·64	59·731	2·652
5	286·64	263·10	·33	49·84	59·882	2·656
7	241·98	203·18	·31	50·05	60·033	2·660
9	197·32	143·26	·30	50·24	60·184	2·664
11	152·65	83·33	·28	50·45	60·335	2·668
13	107·99	23·41	·27	50·64	60·486	2·672
15	63·31	323·48	·26	50·83	60·637	2·676
17	18·65	263·55	−0·24	51·00	60·788	−2·680

The times of passage of the zero meridian of either system across the centre of the illuminated disc may be found by the method given on p. 31.

7 Vanbrugh Park Road, Blackheath, S.E.:
1898 *January* 19.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. FEBRUARY 11, 1898. No. 4

Sir R. S. Ball, LL.D., F.R.S., President, in the Chair.

Samuel Cooke, M.A., Principal of the College of Science, Poona, India;
Thomas Charlton Hudson, B.A., Nautical Almanac Office, 3 Verulam Buildings, Gray's Inn, W.C., and 83 Dresden Road, Upper Holloway, N.;
David Hunter, John O'Groats Villa, Cambuslang, Glasgow;
Edmund Taylor Whittaker, B.A., Trinity College, Cambridge; and
Walter Wickham, Radcliffe Observatory, and 62 St. John's Road, Oxford,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Captain Vernon L. D. Broughton, Hillside, South Godstone, Surrey (proposed by Duncan Forbes);
Charles Friswell, 34 Madeley Road, Ealing, W. (proposed by J. McCarthy);
Professor C. J. Joly, M.A., Royal Astronomer of Ireland, the Observatory, Dunsink, co. Dublin (proposed by A. A. Rambaut); and
William Ritchie, Mathematical and Science Teacher, 75 Morningside Road, Edinburgh (proposed by William Peck).

Report of the Council to the Seventy-eighth Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
1896 December 31	253	391	644	40	1	685
Since elected	+ 3	+ 18	...	...	...	...
Deceased	− 14	− 10	...	− 2	...	...
Resigned	...	− 7	...	...	...	...
Removals	+ 2	− 2	...	...	...	...
Expelled	...	− 3	...	...	...	...
1897 December 31	244	387	631	38	1	670

Mr. Knobel's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1897 January 1 :—						
At Bankers'	186	12	1			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	14	13	1			
In hand of Assistant Secretary on Petty Cash Account	0	12	4			
				201	17	6
Dividends on £13,200 Consols, 2¾ per cent. ...	350	18	4			
1 quarter's dividend on £900 New 2½-per-cent. Stock	5	8	9			
3 quarters' dividends on £932 19 0 Metropolitan 2½-per-cent. Stock	16	18	3			
Dividends on £1,250 Metropolitan 3-per-cent Stock	36	5	0			
				409	10	4
Received on account of Subscriptions :—						
Arrears	153	6	0			
Annual Contributions for 1897	600	12	0			
" " 1898	6	6	0			
Admission Fees	46	4	0			
First Contributions	31	10	0			
				837	18	0
Composition Fees				105	0	0
Sales of Publications :—						
At Williams and Norgate's, 1896	34	5	7			
At Society's Rooms, 1897	60	13	9			
Sale of Photographs, 1897	16	12	0			
				111	11	4
Sale of £900 New 2½-per-cent. Stock				952	16	6
Income Tax refunded by Commissioners of Inland Revenue				14	1	8
Outstanding Cheques				6	12	0
				£2,639	7	4

Astronomical Society, from 1897 *January* 1 *to December* 31.

EXPENDITURE.

	£ s. d.	£ s. d.
Assistant Secretary: Salary	250 0 0	
" " for assistance in editing Society's Publications ...	50 0 0	
		300 0 0
House Duty	2 12 6	
Fire Insurance	7 16 6	
		10 9 0
Printing, &c., *Monthly Notices*	464 8 3	
" List of Fellows	7 7 0	
" Miscellaneous	23 1 0	
Lithography, Engraving, etc.	17 11 6	
		512 7 9
Reproduction of Photographs (Photographic Comm.)		18 13 8
Purchase of Photographs	3 12 0	
Turnor and Horrox Fund: Purchases for Library	27 3 11	
Binding Books in Library	15 14 9	
		46 10 8
Alterations and repairs to the Waters Telescope ...		18 2 1
Clerk's Wages	52 0 0	
Postage and Telegrams	74 12 9	
Carriage of Parcels	3 15 0	
Stationery and Office Expenses	3 16 7	
Ditto Spottiswoode & Co.	9 10 6	
		143 14 10
Expenses of Meetings	21 0 0	
Lantern Expenses	8 14 0	
		29 14 0
House Expenses	63 6 4	
Coals and Gas	51 12 10	
Electric Light Expenses	6 9 4	
Time Signal	6 10 0	
Sundry Fittings and Repairs	12 9 9	
Sundries	5 17 4	
		146 5 7
Haden & Son, new heating boiler, etc.		115 12 4
Illuminating address...	4 15 0	
A. Wyon, 5 Gold Medals	52 10 0	
		57 5 0
Jackson Gwilt Fund: 5 Bronze Medals, etc. ...	12 2 0	
" " Grant to Lewis Swift ...	25 0 0	
		37 2 0
Lee and Janson Fund Grant		5 0 0
Deductions on Cheques	0 1 11	
Cost of power of attorney	0 11 6	
Cost of American draft	0 1 0	
Cheque book	0 8 4	
		1 2 9
Purchase of £932 19 0 Metropolitan 2½-per-cent. Stock		952 16 6
Balances, 1897 December 31:—		
At Bankers'	239 1 9	
In hand of Assistant Secretary on account of Turnor and Horrox Fund	5 9 2	
In hand of Assistant Secretary on Petty Cash Account	0 0 3	
		244 11 2
		£2,639 7 4

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1897, and have found and certified the same to be correct. The cash in hand on December 31, 1897, including the balance at the bankers', &c., amounted to £244 11*s.* 2*d.*

The funded property of the Society is the same as at the end of last year, except that £900 $2\frac{1}{2}$ per cent. Consols have been sold, and £932 19*s.* Metropolitan $2\frac{1}{2}$ per cent. stock has been bought with the proceeds.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(Signed) RICHARD INWARDS,
F. W. LEVANDER,
A. C. D. CROMMELIN.

1898 *February* 2.

Trust Funds.

The Turnor Fund: A sum of £450 $2\frac{3}{4}$-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £100 $2\frac{3}{4}$-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £323 16*s.* 6*d.* $2\frac{3}{4}$-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £300 $2\frac{3}{4}$-per-cent. Consols, the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1898 *January* 1.

	£	s.	d.	£	s.	d.
Balances, 1897 December 31:—						
At Bankers'	239	1	9			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	5	9	2			
In hand of Assistant Secretary on Petty Cash Account	0	0	3			
	244	11	2			
Less outstanding cheques	6	12	0			
				237	19	2
Due on account of Subscriptions:—						
2 Contributions of 4 years' standing... ...	16	16	0			
16 " 3 "	100	16	0			
31 " 2 "	130	4	0			
58 " 1 "	121	16	0			
1 Admission Fee and First Contribution ...	3	3	0			
	372	15	0			
Less 3 Contributions for 1898 paid in advance	6	6	0			
				366	9	0
Due from Messrs. Williams and Norgate for sales of Publications during 1897				1	13	1

£13,200 2¾-per-cent. Consols, including the Lee and Janson Fund, the Turnor and Horrox Fund, and the Jackson-Gwilt Fund.

£1,250 Metropolitan 3-per-cent. Stock.

£932 19 0 Metropolitan 2½-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

Four Gold Medals.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	149	1
I. Part 2	41	...	XXXI.	135	...
II. Part 1	50	3	XXXII.	146	...
II. Part 2	15	3	XXXIII.	155	...
III. Part 1	64	1	XXXIV.	158	1
III. Part 2	82	1	XXXV.	104	2
IV. Part 1	76	3	XXXVI.	187	8
IV. Part 2	89	3	XXXVII. Part 1	332	7
V.	100	3	XXXVII. Part 2	278	8
VI.	117	6	XXXVIII.	263	1
VII.	140	3	XXXIX. Part 1	228	3
VIII.	124	3	XXXIX. Part 2	233	3
IX.	131	3	XL.	248	1
X.	143	...	XLI.	395	1
•XI.	150	...	XLII.	224	3
XII.	156	...	XLIII.	225	...
XIII.	154	...	XLIV.	206	1
XIV.	362	...	XLV.	238	...
XV.	135	...	XLVI.	217	1
XVI.	159	1	XLVII. Part 1	3	...
XVII.	142	1	XLVII. Part 2	18	...
XVIII.	136	1	XLVII. Part 3	2	...
XIX.	146	...	XLVII. Part 4	10	...
XX.	135	1	XLVII. Part 5	8	...
XXI. Part 1	310	...	XLVII. Part 6	9	...
XXI. Part 2	98	...	XLVII.	190	...
XXI. 1 & 2 (together)	57	...	XLVIII. Pt. 1	241	...
XXII.	159	1	XLVIII. Pt. 2	233	1
XXIII.	143	...	XLIX. Part 1	378	1
XXIV.	150	1	XLIX. Part 2	258	1
XXV.	160	...	L.	248	1
XXVI.	166	1	LI.	310	1
XXVII.	418	1	Index to *Memoirs*	619	3
XXVIII.	376	...			
XXIX.	397	1			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	54	...	XXXI.	91	...
II.	58	...	XXXII.	108	5
III.	...	...	XXXIII.	90	...
IV.	...	...	XXXIV.	68	1
V.	...	...	XXXV.	52	...
VI.	42	...	XXXVI.	26	1
VII.	2	...	XXXVII.	33	3
VIII.	153	2	XXXVIII.	96	2
IX.	24	3	XXXIX.	93	...
X.	172	1	XL.	105	3
XI.	184	...	XLI.	105	5
XII.	106	2	XLII.	113	1
XIII.	177	2	XLIII.	111	2
XIV.	176	3	XLIV.	114	2
XV.	167	2	XLV.	115	1
XVI.	154	1	XLVI.	110	...
XVII.	167	1	XLVII.	127	2
XVIII.	242	...	XLVIII.	117	1
XIX.	52	...	XLIX.	112	8
XX.	31	...	L.	111	10
XXI.	16	...	LI.	114	8
XXII.	30	...	LII.	114	12
XXIII.	17	...	LIII.	115	15
XXIV.	22	...	LIV.	115	16
XXV.	13	...	LV.	129	3
XXVI.	9	1	LVI.	133	6
XXVII.	3	...	LVII.	136	8
XXVIII.	70	...	1st Index ...	548	3
XXIX.	50	...	2nd " ...	845	...
XXX.	62	2			

Library Catalogue 546 2

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LVII., no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
" 2. The *Owen* portable circles, by Jones.
" 3. The *Beaufoy* circle.
" 4. The *Beaufoy* transit instrument.
" 5. The *Herschel* 7-foot telescope.
" 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
" 7. The *Smeaton* equatorial.
" 8. The *Cavendish* apparatus.
" 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
" 10. The variation transit instrument (late Mr. Shearman's).
" 11. The universal quadrat, by Abraham Sharp.
" 12. The *Fuller* theodolite.
" 13. The standard scale, by Troughton and Simms.
" 14. The *Beaufoy* clock, No. 1.
" 15. The *Beaufoy* clock, No. 2.
" 16. The *Wollaston* telescope.
" 17. The *Lee* circle.
" 18. The *Sharpe* reflecting circle.
" 19. The *Brisbane* circle.
" 20. The *Baker* universal equatorial.
" 21. The *Reade* transit.
" 22. The *Matthew* equatorial, by Cooke.
" 23. The *Matthew* transit instrument.
" 24. The *South* transit instrument.
" 25. A sextant, by Bird (formerly belonging to Captain Cook).
" 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

" 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
" 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.

No. 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$-inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.

„ 30. (4) $3\frac{1}{4}$-inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single

minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

No. 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21) Box sextant; reflecting plane and level.

„ 48. (22) Prismatic compass, by Troughton and Simms.

„ 49. (23) Mountain barometer.

„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25) Ordinary 4½-inch compass with needle.

„ 52. (26) Dipping needle, by Robinson.

„ 53. (27) Compass needle, mounted for variation.

„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29) Box of magnetic apparatus.

„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.

„ 58. (32) Plane 2⅝-inch speculum, artificial horizon and stand.

„ 59. (33) 2½-inch circular level horizon, by Dollond.

„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.

„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.

„ 62. (36) A pantograph.

„ 63. (37) A noddy.

„ 64. (38) A small Galilean telescope with object-glass of rock crystal.

„ 65. (39) Five levels.

„ 66. (40) 18-inch celestial globe.

„ 67. (41) Varley stand for telescope.

„ 69. (43) Telescope, with object-glass of rock crystal.

„ 71. Portable altazimuth tripod.

„ 72. Four polarimeters.

„ 74. Registering spectroscope, with one large prism.

„ 76. Two five-prism direct-vision spectroscopes.

„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.

„ 79. Spectroscope.

„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.

No. 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. $4\frac{1}{2}$-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. $3\frac{1}{2}$-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
„ 91. Astronomical time watch-case, by Professor Chevalier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. } Two old sun-dials.
„ 118. }

No. 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
„ 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-inch portable refracting telescope, by Tulley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere.
„ 130. 10-inch brass pillar sextant with counterpoise stand, by Troughton.
„ 131. Double box sextant, by Cary.
„ 132. Equatorially mounted camera with 2½-inch portrait lens and telephotographic enlarging lens by Dallmeyer; iron pillar. [Presented by the executors of the late Sidney Waters.]
„ 133. 3¼-inch equatorial by Ross, with tall tripod stand, equatorial mounting, eyepieces, and micrometer. [Presented by Mrs. Mann.]

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.
2 Abney lenses used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
1 Cœlostat with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 22. The *Matthew* equatorial, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. (1) 30-inch transit and stand, to Mr. B. T. Moore.
„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.
„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.
„ „ Wire micrometer (No. 2), to the Rev. C. D. P. Davies.

No. 31. (5) 2¾-inch telescope and stand, to Mr. F. J. Wardale.
,, 42. (16) Artificial horizon, roof, and mercury bottle, to Mr. F. Robbins.
,, 47. (21) Box sextant and horizon, to Mr. C. H. Johns.
,, 50. (24) Prismatic compass, to Mr. Maxwell Hall.
,, 57. (31) Box sextant, to Dr. A. A. Common.
,, 69. (43) Telescope with rock-crystal object glass, to Sir W. Huggins.
,, 72. (*c*) Polarimeter, to Professor C. Michie Smith.
,, 76. (*b*) 5-prism direct-vision hand spectroscope, to Mr. E. W. Ellerbeck.
,, 85. Double-image micrometer, to Mr. B. T. Moore.
,, 119. Diffraction gratings, to Mr. B. T. Moore.
,, 123. 6-inch telescope, by Grubb (object-glass only) to Mr. W. E. Wilson.
,, 124. Position micrometer, by Cooke, to Mr. T. K. Mellor.
,, 125. 6-inch refractor by Simms, to Dr. A. A. Common.
,, 126. 3½-inch portable refractor, by Tulley, to Mr. H. Sadler.
,, 128. Bichromate battery, to the Rev. W. J. B. Roome.
,, 131. Double sextant, by Cary, to Mr. F. Robbins.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Mr. W. F. Denning, for his meteoric observations, his cometary discoveries, and other astronomical work. The President will lay before the Society the grounds upon which the award has been founded.

The Library.

A supplementary catalogue, containing the additions to the library from 1884 June to 1897 June, is in preparation and will shortly be published.

Obituary.

The Council regret that they have to announce the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Antoine d'Abbadie.
J. W. Aldridge.
J. T. Barber.
Adolphe de Boë.
Frederick Brodie.
L. P. Casella.
H. B. Chamberlin.
J. J. Cole.
Samuel Cottam.
Rev. J. E. Cross.
T. G. E. Elger.*
Rev. Alexander Freeman.
William Godward.
Adam Hilger.
Rev. T. Mackereth.*
Joseph Maguire.
Albert Marth.
J. C. Robertson.
William Roxburgh.
Commander J. M. Share.
Charles Stewart.
E. J. Stone.
W. R. Vines.
C. C. Walker.

Associates :—Wilhelm Döllen.
F. A. T. Winnecke.

Antoine Thompson d'Abbadie was born in Dublin, of French parents, in the year 1810. His family returned to France in 1818, where he was educated. He early devoted himself to the study of geography, geodesy, and terrestrial magnetism. In 1836 August he determined the magnetic inclination at Paris. In 1837 he went to Olinda, in Brazil, where he studied the diurnal variations of the needle between the magnetic and terrestrial equators. The details of these observations were not

* Obituaries published 1897 Annual Report.

published till 1873, when they appeared in a memoïr, entitled "Observations relatives à la Physique du Globe faites au Brésil et en Ethiopie." From 1837 to 1839 he was engaged with his brother, Michel Arnauld d'Abbadie, in making his first exploration of Ethiopia, and a second voyage was undertaken in the period 1839 to 1849. It is certain, however, that for some time in 1839 he was in Paris, as he there made a second determination of the magnetic inclination, to compare with that made three years previously. The results of these twelve years' geographical and geodetical work were published in 1873, under the title "Géodésie d'Ethiopie, ou Triangulation d'une Partie de la Haute-Ethiopie, exécutée selon des Méthodes Nouvelles."

What characterised the work of d'Abbadie was his method of observation. He had recognised how little precision attached to independent determinations of geographical positions—that is to say, those which are determined directly from observations of stars by field instruments, of which the best are exact only to about one or two kilometres. He conceived the plan, entitled "Géodesie Expeditive," of forming a network of triangles, more or less well proportioned, which included all the natural signal points that could be seen from the improvised stations on the heights where the party halted. This method gives a precision ten times greater than that of independent positions, and affords a valuable means of verification. Thus a connected chain of triangles was formed from the shores of the Red Sea to the confines of the country of Kaffa. This network included 8° 32′ in latitude and 3° in longitude, and furnished the positions of 857 points, confirmed also by the absolute determinations of a great number of latitudes, of longitudes from occultations, and of altitudes barometrically or hypsometrically determined. These observations were for the most part made with a small theodolite, which he had improved by placing the telescope parallel to the horizontal limb. This telescope, turning about an axis, can be pointed, by means of a prism before the object-glass, upon every object in azimuth or altitude. To this new form of geodetic instrument he gave the name of "Aba."

In the year 1851 d'Abbadie went to Frederiksvaern, in Norway, to observe the solar eclipse of that year, when he made some polariscopic observations of the prominences and corona, employing a 3·9-inch telescope, and power of 52, with a quartz plate and double-image prism. In 1860 he went to Spain, and observed the solar eclipse at Briviesca, again making polariscopic observations. In 1867 he observed at Algiers the annular eclipse of March 6. In 1882 he was the chief of the expedition sent out by the Académie des Sciences to Haiti to observe the Transit of *Venus*. In 1874 d'Abbadie sent a communication to the *Monthly Notices*, calling attention to an error he had discovered in the Radcliffe Catalogue. He erected an observatory at his Château d'Abbadia (Basses-Pyrénées), where he devoted himself to investigating the periodic variations of the deviation of the vertical.

The Geodesy of Ethiopia was the greatest work of D'Abbadie's life, and was a contribution to geographical science of the highest value. For though his results were some time ago seriously questioned, more recent researches have triumphantly established his triangulation, and proved the trustworthy character of the work done by him in this remote region. But D'Abbadie was also illustrious by reason of his varied researches, contained in numerous memoirs and notes communicated to the "Académie des Sciences," the "Société de Géographie," and to many other scientific societies, on astronomy, geodesy, physics, meteorology, geography, ethnography, and philology. The citation of the following titles will indicate the nature of some of his more important researches: "Études grammaticales sur la Langue Euskarienne" (1836); "Sur la Langue Kamtiga" (1841); "Sur la Langue Saho" (1843); "Découverte de la Source du Gibé ou Uma" (1847); "Résumé des Voyages faits par MM. Antoine et Arnauld d'Abbadie" (1849); "Note sur le Haut Fleuve Blanc" (1849); "Documents sur la Géographie du Bassin du Nil" (1852); "Sur les Tremblements de Terre et les Mouvements du Sol" (1852); "Mémoire sur le Tonnerre en Éthiopie" (1858); "Résumé Géodesique des Positions déterminées en Éthiopie" (1859); "Catalogue raisonné de MSS. Éthiopiens, comprenant 234 MSS." (1859); "Description d'un Instrument pour la Pratique de la Géodesie Expéditive" (1863); "Sur une Nouvelle Lunette Zénithale" (1865); "Études sur la Verticale" (1872); "Recherches sur la Verticale" (1882); "Les Fluctuations des Latitudes Terrestres" (1892); "Géographie de l'Éthiopie" (1883), &c. &c.

M. d'Abbadie belonged to the Institut de France for forty years, and for nearly twenty years he had been a member of the Bureau des Longitudes. Simple in his manner and kind-hearted in his nature, he was ever ready to give assistance to those who appealed to him for advice, and his loss is deeply regretted by all who were favoured with his acquaintance. He died in Paris 1897 March 19, at the age of eighty-seven years, signalising his love for Astronomy by bequeathing an estate in the Pyrenees, yielding 40,000 francs a year, to the Académie des Sciences, on condition of its publishing, within fifty years, a General Catalogue of Stars.

He was elected a Fellow of the Society on 1895 November 8.

John William Aldridge was born in London on 1824 August 24. His interest in astronomy was first roused by observing Halley's Comet at its return in 1835, but he never undertook any practical work in the science. He had no occupation, and devoted himself to extensive reading, not only in astronomy but also in law and medicine, and he was interested in cuneiform inscriptions. He was a regular attendant at the meetings of the Society when his health permitted. He died on 1897 December 11.

He was elected a Fellow of the Society 1890 May 9.

John Thomas Barber was born at Derby, 1825 July 23, and died at Norwood 1897 March 25. In 1854 he married Jane, eldest daughter of the late Rev. Matthew With. From 1864 till 1883 he lived at Spondon, in Derbyshire, and from 1883 till his death at Hoperay, Aston-on-Clun, Salop. He was of independent means. Mr. Barber took a keen amateur's interest in astronomy from the time when he was an undergraduate at Cambridge. In 1847 he published, together with Mr. J. Morgan, an illustrated account of the Great Aurora on October 24, as seen from the Cambridge Observatory, together with the auroras of 1846 September and 1847 March, and he calculated ephemerides for the return of comets. He set up at Spondon an 8-inch equatorial by Cooke, of York, and made observations with it of a miscellaneous kind; but the telescope was not re-erected in the unfavourable situation of Aston-on-Clun. He was elected a Fellow of the Society on 1849 December 14.

Gustave Adolphe de Boë was born at Tamise in 1821. His childhood was spent at Douai, with his uncle, and he was educated, first at Lille and then at Brussels. His family lived at Antwerp, whither he returned in 1841, after a year spent in London in acquiring a thorough knowledge of English. It was not until 1858 that his interest in astronomy was awakened by reading Arago's *Astronomie Populaire*, then in course of publication. He was fascinated by what he read, and founded a private observatory at Antwerp (the first of its kind in Belgium), where he made numerous observations, both astronomical and meteorological. Among them may be mentioned the accurate determination of the latitude and longitude of his observatory, and his observations of the Transit of *Mercury* in 1878 and of the Transit of *Venus* in 1882. He was fertile in suggesting ingenious devices: the use of a daguerrotype plate in the mercury-trough; a simple equatorial mounting; a method of measuring the magnifying power of a telescope, &c., &c.; and, finally, perhaps his best work as an astronomer consisted in the interest which his own enthusiasm for the science awakened in others. His observatory (furnished with a 6-inch equatorial by Secretan, a small transit circle, a comet seeker, clocks, &c.) and his well-equipped library were always open to those interested in astronomy; and he did much by writing in magazines and the daily papers to disseminate a knowledge of the chief facts and most important events.

He was elected a Fellow of the Society on 1881 January 14.

Frederick Brodie was born at Eastbourne, Sussex, on 1823 July 19, and was the youngest son of the Rev. Alexander Brodie, D.D., then Vicar of Eastbourne, a cadet of the ancient Scotch family of Brodie of Brodie, in the county of Nairn. His mother was Anna, daughter of John Walter, M.P., the founder of the *Times*. Mr. Brodie was educated at a private school at

Eastbourne and at the University of Edinburgh. His inclinations leading him in the direction of civil engineering, he was articled to Mr. J. M. Rendel, and in that capacity took part in the construction of the Chester and Birkenhead Railway. His connection with that undertaking led to his being appointed to a post in India in the early days of the Indian railways (1848), but when everything was settled, and his foreign service kit prepared, the promoters of the railway decided to cut down their expenditure, and Mr. Brodie refused to take up his appointment at a reduced salary. He remained therefore in England, and became Resident Engineer at the Esher Paper Mills, and continued there till he retired from his profession on his marriage, in 1853, with Elizabeth Anne, daughter of Mr. Thomas Fussell, of Wadbury House, Frome, Somersetshire, then the proprietor of the Mells Iron Works. Mr. Brodie erected in the grounds at Wadbury an observatory, proposing to carry on general astronomical work. The death of his wife in the spring of 1854 led him to quit Somersetshire, and the observatory was removed to an excellent site in a field belonging to his mother at Eastbourne, where he resided until after his second marriage, in 1858, to Ada Blanche, third daughter of the late Sir Robert W. Carden, Bart., M.P. He moved to Uckfield, in Sussex, in 1859, where for eighteen years he carried on observations of various kinds. The climate of Uckfield proving unsuited to his wife, who was never well there, Mr. Brodie sold his Uckfield property and bought a larger and better situated house, known as Fernhill, near Wootton, in the Isle of Wight, four miles west of Ryde. He died there on 1896 August 14, leaving, by his second wife, three sons and one daughter, two other children having died young.

Mr. Brodie's first observatory is described in vol. xvi. of the *Monthly Notices*, and was a remarkably successful structure as regards cheapness, lightness, and portability. It was made entirely of deal boards, and in planning it Mr. Brodie's engineering skill and experience stood him in good stead. A specification and plans, as modified by Mr. Brodie himself for the purpose, are given in the third volume of Chambers's *Handbook of Descriptive Astronomy*. The telescope with which Mr. Brodie started his astronomical work was an excellent $6\frac{1}{3}$-inch refractor. The object-glass was by Merz, of Munich, but the tube and mounting were made in England under Mr. Brodie's own superintendence. This telescope was afterwards sold to Sir William Keith Murray, of Ochtertyre, N.B., and was replaced by an American object-glass by Alvan Clark, of Boston, U.S., of $7\frac{1}{3}$ inches aperture, which had belonged to Mr. Dawes. On Mr. Brodie settling at Uckfield he sold his observatory and equatorial stand to Mr. C. L. Prince, by whom it was re-erected at Uckfield, the American object-glass being mounted in a new tube and on a new stand supplied by Mr. T. Cooke, of York. When Mr. Brodie broke up his establishment at Uckfield, in 1877, he remained houseless for about a couple of years, in which interval he went out to the

Cape of Good Hope, with some idea of remaining there for a time and carrying out astronomical observations there, but he was disappointed with the climate, and did not stay long in the colony, and eventually settled in the Isle of Wight, as stated above.

Mr. Brodie was a painstaking and accurate astronomical observer, and though his published contributions to our science were few and far between, he left behind him a large mass of memoranda (especially on Sun-spots and star clusters), selections from which might well be given to the world. Born and brought up a member of the Church of England, he quitted the Church in middle life and took up the tenets of the Plymouth Brethren, more or less, and turned his attention to the composition and publication of religious books, becoming himself a lay preacher. This eventually led to his abandoning, practically, all astronomical work, but his telescope was often used by his eldest son, Dr. C. G. Brodie, during his father's lifetime, and will probably be much more used in the future. Finally, it may be stated that Mr. Brodie was a very capable amateur carpenter, turner, and pyrotechnist, and, besides all that, was a great printer, having set up a large and well-equipped printing-office in each of his successive residences. He was elected a Fellow of the Society on 1855 February 9. G. F. C.

Louis Pascal Casella was born in Edinburgh in the year 1809. His father was a member of an old Italian family, and his mother was the daughter of General Ramsey, of Edinburgh. He was educated at Edinburgh, and at the age of twenty-seven he joined his father-in-law, the late Mr. Tagliabue, as an instrument maker, and eventually succeeded to that business. In the construction of meteorological, surveying, and engineering instruments, Mr. Casella attained a very high excellence, due to his innate intellectual skill and ability, and many important improvements and inventions in scientific instruments were made by him. Two inventions may be mentioned as being always associated with his name : the clinical thermometer, based upon Professor Phillips' maximum thermometer, which was brought into general use by the joint labours of Sir W. Aitken and Mr. Casella ; and the adaptation of the pressure gauge to the verification of thermometers for determining the temperature at great depths in the ocean where the pressure per square inch of surface can only be adequately expressed in tons. Mr. Casella did not do much work as an astronomer, but the indirect assistance he gave to astronomy by the excellent meteorological instruments he made has closely associated his name with many observatories. Mr. Casella's benevolence and kindly disposition were well known, and attracted to him wide respect. He died on 1897 April 23, at his residence at Highgate, at the advanced age of eighty-nine years. He was elected a Fellow of the Society 1860 June 8.

Humphrey Barker Chamberlin was born at Manchester in 1847, and died on 1897 May 16, at Egham, Surrey. At the age of seven he was taken to America by his parents, and served in the Military Telegraph Service Corps during the Civil War. He subsequently entered the drug business, combining a sound knowledge of chemistry with much commercial aptitude. In 1879 he suffered greatly from nervous trouble, which affected his eyes and made reading almost impossible. During the enforced leisure caused by this breakdown he made a small telescope, and started the interest in astronomy that continued until his death. In 1888 he determined to present a telescope to the University of Denver. With characteristic large-heartedness, he wrote to Dr. Howe, asking him to say, perfectly frankly, what telescope he would like, regardless of pecuniary limitations. Dr. Howe selected an aperture of 20 inches, and Mr. Chamberlin's reply was that "the question of a 20-inch telescope has been referred to the committee of ways and means, and I look for a favourable response." He was his own committee, and the response *was* favourable. He shortly after presented the University of Denver with two buildings, one for the main instrument and the library, the other for purposes of instruction—the students' observatory. The University set aside a plot of 14 acres in the outskirts of Denver, 4500 feet above the sea, for the site of the observatory, and the great telescope was installed in the summer of 1894. The 20-inch object-glass is by Clarke, and the mounting by Saegmuller.

Mr. Chamberlin was also greatly interested in mineralogy and microscopy. He founded a Microscopical Society in Denver, to which he presented a technical library. Not the least important work that he did for science was that of paying the expenses of a sound scientific training, in an unobtrusive way, for many young men with whom he came in contact.

Since 1890 Mr. Chamberlin resided chiefly in London. While here he founded the American Society in London, a task which his social qualities enabled him to accomplish with much success. He travelled extensively, and always made a point of seeing as many important observatories at home and abroad as he could.

He was married in 1871, and his widow and three children survive him. He was elected a Fellow of the Society on 1892 May 13. W. S.

John Jenkins Cole was born on 1815 March 25, at Plymouth. His father, Robert Cole, was a solicitor, who afterwards practised in London, and was well known as an antiquary. He was trained as a solicitor, but became an architect, and among the buildings designed by him in the course of a long working life may be specially mentioned the church of St. Mary, Abberley; Sir E. Antrobus's house at 146 Piccadilly; the offices of the Gresham Life Assurance Society opposite the Mansion House, and several

buildings in Throgmorton Street. He was architect to the Stock Exchange for 35 years, and designed the new Dome (forming a large extension of the "House" or market), the new offices in Throgmorton Street, and the long frontage in Old Broad Street, erected in 1882–88, besides carrying out numerous alterations and additions before and after those dates. He never undertook any astronomical work, though he was fond of looking through his own telescope, and he "had the pleasure (at Sutton, Surrey) of a clear observation of the Transit of *Mercury* in 1878," but he followed the work of others with keen interest, and was much attached to our Society, which he joined in 1862 March. About a fortnight before his death, and in anticipation of it, he desired his wife to write to the Secretary of the Society indicating some of the facts here mentioned, and specially recording that his greatest comfort was that he had been one of the fathers of sanitary science, and the means of abolishing the terrible system of *one* water cistern for all purposes the civilised world over. With the letter was enclosed a reprint of a letter in the *Times*, dated 1856 August 4, calling attention to this system, and its great dangers during the cholera epidemic of that time, suggesting the immediate erection of stand-pipes for drinking purposes and the ultimate abolition of the single-cistern system. The stand-pipes were set up forthwith, and Mr. Cole lived to see his principles universally adopted. While a member of the Society he resided successively at 24 Essex Street, Strand, at Hornsey Rise, and at Mayland, Sutton, Surrey, where he had a large room built for his telescopes. He died in this house on 1897 May 10, aged 82. He was twice married, and his wife, three sons, and a daughter survive him. He was elected a Fellow of the Society 1862 March 14.

Samuel Cottam was born 1828 December 3 in Manchester, where the Cottams have held a prominent position for more than a century. [The family claims descent, according to a tradition, from Kotta the Dane.] He was a chartered accountant, head of the firm of Messrs. S. E. Cottam and Son; a man of marked business capacity, and an excellent financier. He did not live to retire, for, though an invalid, he carried on work at his residence, Wightwick House, Higher Broughton, where he died 1896 September 1. He married, in 1858, Mary, youngest child of John Justin Southam, and two children survive—a son in orders, and a daughter who is an artist. Mr. Cottam was a man of varied attainments—a water-colour painter and a musician, a keen gardener and photographer, and a traveller in days when travelling was not so easy as now.

He was elected a Fellow of the Society on 1871 January 13.

The Rev. John Edward Cross was born at Red Scar, Preston, Lancashire, 1821 April 10, the son of William Cross. He was educated at Rugby and Christ Church, Oxford, and ordained in

1846 to a curacy in Bolton, where he remained till 1849, when he became curate and then vicar of Appleby, in Lincolnshire. He married, in 1854, Elizabeth, daughter of Admiral Sir Phipps Hornby, Rear Admiral of England. He became Prebendary of Leicester St. Margaret's in 1880, and in 1882 Rural Dean of Manlake. He resigned the living of Appleby in 1891, and went to live at Halecote, near Grange, Westmoreland. His health failed soon after, and he died, after a long and painful illness, at Scarborough, 1897 February 28.

Canon Cross was interested in astronomy from boyhood. One of his earliest recollections at Rugby was that of an eclipse of the Sun, on Sunday afternoon 1836 May 15, when Dr. Arnold altered the hour of divine service so as to allow the boys to watch the phenomenon. During his curacy in Bolton he made good use of a small telescope which ultimately became the finder to a larger equatorial. At Appleby he built a good observatory; and the mirrors for his large reflector were polished by his brother William.

[This brother, Colonel William Assheton Cross, who died in 1883, was also a Fellow of our Society. From the notice in the Council Report for 1884 February it is clear that the two brothers had much in common. Colonel Cross was educated at Rugby and Trinity, Cambridge; and in his college days had mounted a 5-inch by Dollond, once the property of the Rev. W. R. Dawes. From Lassell he learnt to grind mirrors, and made a 15-inch of great excellence, which he mounted equatorially. The following sentence is interesting from several points of view: "By a rude stroke of fate, one which denotes the rapid strides that have been made in the size of astronomical instruments in the course of one generation, Dawes's refractor, mentioned above, was degraded to become the finder of the new reflector." It may here be mentioned that the only surviving brother is the Right Hon. Viscount Cross, Lord Privy Seal.]

Canon Cross was, however, more interested in transit observations than in using his reflector. In his summer holidays, which were always spent in Rannoch, he took great interest in collecting all the details, and, as far as possible, discovering the stations used in the last century by Maskelyne in the Schehallien experiment; and though he never identified the actual spot where the principal observations were taken, he got a good approximation to it.

He was elected a Fellow of the Society on 1862 May 9.

Alexander Freeman was born in London 1839 January 28. He was educated at Merchant Taylors' School, and at St. John's College, Cambridge, where he graduated in 1861 as fifth wrangler. He was elected a Fellow of his college in 1862 May, and in the same year he obtained the Chancellor's medal for legal studies. Soon after this he took holy orders, and became M.A. in 1864.

Soon after taking his degree Mr. Freeman devoted himself to astronomy, which was the great love of his life. His first pub-

lished communication was to the *Messenger of Mathematics* in 1863, "on the variations of the node and inclination of a disturbed planet deduced from the lunar equation of latitude." Some further papers were published in the same periodical, in the *Proceedings* of the Cambridge Philosophical Society, and in volumes of the *Monthly Notices* from 1872 to 1892. These included observations of *Saturn's* ring, and occultations of stars by the Moon, and an interesting paper on a graphic conversion of stellar coordinates. In 1878 he published with notes a translation of Fourier's "Analytical Theory of Heat," which was produced by the Cambridge University Press. He also edited the third edition of Cheyne's *Planetary Theory*.

From 1880 to 1882, during the illness of the late Professor Challis, Mr. Freeman was appointed as his deputy, and he lectured for him on "Practical Astronomy and the use of Astronomical Instruments." On two occasions Mr. Freeman examined for the Smith's prize.

In 1882 Mr. Freeman married the daughter of Colonel Paterson, of the Buffs, and soon after that he was appointed Rector of Murston, near Sittingbourne, in Kent, which position he held until his death. Here he was greatly respected, and his kind, courteous and amiable manner made him a great favourite in the neighbourhood. He had always hoped to obtain an astronomical appointment, which would have been so congenial to his tastes, but in this he was unsuccessful.

He was a great reader and a hard-working man, and was always engaged in some astronomical work. He possessed an observatory with a $6\frac{1}{2}$-inch refractor, by Grubb, with which he spent the happiest hours of his life. About three years ago Mr. Freeman fainted while on a visit to the Archbishop of Canterbury, at Addington, and was compelled to take a three months' rest. He still, however, insisted on working hard, with the result that in 1897 March he had another prostration, from which he never recovered, and was confined to his room till June, when he died. This long and painful illness was borne most uncomplainingly, and throughout it he did all he could for his parish and for the large school of 400 children attached to his church. Mr. Freeman has left a widow and four children—three daughters and a boy.

He was elected a Fellow of the Society 1864 January 8.

William Godward was born in 1829 at Wakefield, where his father was a schoolmaster. At the age of eighteen he entered the *Nautical Almanac* Office, where his father and his uncle (William and John Godward) were at that time also serving, under Lieutenant Stratford; and he remained there for the long period of forty-three years, being appointed to the Chief Assistantship in 1869 on the retirement of Mr. Richard Farley. Among several improvements contributed by him to the *Nautical Almanac* may be specially mentioned his interpolation tables, which superseded others of a much more laborious character, and

are still in use; as are also his improved elements of *Ceres*, given in the only paper he ever contributed to this Society (*Monthly Notices*, vol. xxxviii. p. 119). In 1866 he published his "Auxiliary Tables for Computing an Approximate Ephemeris of a Minor Planet." He retired from office on account of the age-limit in 1890, and died on 1897 May 19.

He was elected a Fellow of the Society on 1872 January 12.

Adam Hilger was born in Darmstadt in 1839, and in his early youth he showed a marked inclination for the mechanical work in which his father was then engaged. For some years he worked as a mechanical engineer in the Mint at Darmstadt, and afterwards entered Ertel's famous establishment at Munich. He next came to London, but soon left for Paris, where he had the good fortune to find employment with the firm of opticians, Lerebours & Secretan. During this engagement he constructed many instruments under the direct supervision of Foucault, and became acquainted with the theory as well as the practice of his art. After the war of 1870 he came to London, and became foreman with Mr. John Browning. Having completed a five years' contract he began business on his own account in Stanhope Street.

In the early memoirs of the pioneers in celestial spectroscopy both at home and abroad, references to Hilger's name are frequently to be found. He supplied many of the instruments with which the researches were carried out, thus gaining reputation and experience which he never ceased to increase. At the time of his death he was engaged upon work for all parts of the world, and his loss will be widely felt. He was always ready to undertake new work in which special difficulties had to be met, and he brought to it not only a wide practical experience but also an eager and active habit of mind. He paid special attention to the cutting and working of quartz and Iceland spar prisms, and had lately made very successful achromatic combinations of lenses, in which only natural crystals were used, and which were specially suitable for work with ultra-violet light.

Amongst many other matters which had engaged his time and thoughts, we may refer to one in particular in the hope that it may receive further attention and be brought to perfection—viz. a form of governor for controlling clockwork in cases where there are considerable variations in the power or the load.

Mr. Hilger died on 1897 April 23, at Brighton, from the effects of a bicycle accident.

He was elected a Fellow of the Society on 1892 February 10.

Joseph Maguire was born at Corstoon, Drumconrath, co. Meath, in or about the year 1800. [The register of his birth cannot be found. He himself believed that he was a centenarian, but evidence, collected after his death, points to the conclusion that his age was ninety-six.] He died on 1896 April 8 at his

residence, 12 Grove Road, Lakenham, Norwich, and was buried with Roman Catholic rites.

He was an able land surveyor, and after being engaged for many years in surveys in the North of England, became managing clerk to Messrs. Wright and Woodrow, the principal land agents in Norwich. He married, in 1864, Miss Harriet Agnes Pettit, daughter of an organist and composer in Norwich. His wife predeceased him, and there was no family. He retired from business some twenty years ago, but continued to live in the same residence till his death.

He contributed several papers to the *Monthly Notices* on eclipses and occultations. His last two papers, published in 1885, give particulars of the thirteen total solar eclipses which have been visible in the British Isles between 878 and 1724, two excellent maps showing the lines of totality. The last sentence of one of these papers may perhaps be quoted:

"It appears from the limiting lines of these eclipses that London has been twice totally eclipsed, Dublin twice, and Edinburgh five times; and, assuming the calculations to be correct, the Moon's shadow would have fallen upon every spot of the British Isles except a small space at Dingle, on the west coast of Ireland."

The calculations were made some ten years before publication of the paper; but even then the author was in the seventies. The tables used were generally Hansen's. Among the papers found at his death was a map of the British Isles showing the course of the 1927 eclipse, which suggests that he contemplated continuing this work, but was no doubt prevented by advancing age. He was elected a Fellow of the Society on 1865 February 10.

Albert Marth was born at Colberg, in Pomerania, on 1828 May 5, and was left an orphan at an early age. The desire of his mother had been that he should enter the Church, but after some time devoted to the study of Hebrew and theology, his early enthusiasm for mathematical science asserted itself, and he resolved to apply himself exclusively to astronomy, which he studied at the University of Berlin, subsequently going to Königsberg, where he became a pupil, and then an assistant of Dr. C. A. F. Peters, professor of astronomy at that university. A schoolfellow of his once said, "Marth may study what he likes, but he is and always will be an astronomer." This early prediction was amply fulfilled in after years, for throughout his life Marth devoted himself solely to that science; indeed, among the numerous memoirs and papers he published, which evince his wide knowledge of general astronomy, we do not find one dealing with any other subject. It cannot be doubted, however, that the influence of a master of such consummate ability as Peters largely contributed to develop in Marth that accurate conception of astronomical problems which he in many ways so conspicuously displayed.

Marth's earlier contributions to astronomy were all published

in the *Astronomische Nachrichten*. In 1852 he published an ephemeris of Westphal's Comet from observations made at Königsberg, and in the following year he made some observations of *Hebe* with the meridian circle of that observatory. In 1853 he became an assistant to Mr. Hind, who was then astronomer at Mr. Bishop's observatory in the Regent's Park, and whilst in that position in 1854 March 1 he discovered the minor planet *Amphitrite* (29), anticipating by one day Pogson's independent discovery of the same planet. He remained at Mr. Bishop's observatory under two years, contributing in that time to the *Astronomische Nachrichten* the elements and ephemerides of the minor planets *Euterpe*, *Amphitrite*, *Massilia*, and *Urania*, besides the elements of Comet I. 1854. In 1855 he succeeded Rümker as astronomer at the Durham Observatory, where he remained till 1862. During this period he published in the *Astronomische Nachrichten* of 1856 August 26 the first part of his "Researches on Satellites." He proposed to investigate the motions of the satellites of *Saturn*, *Uranus*, and *Neptune*, and to elucidate their theories. In this memoir he confined himself to the preliminary mathematical investigations which are necessary, and incorporated new formulæ involved by the principle he adopted. Observations of *Saturn's* satellites had been made by Bessel in the case of *Titan* by measuring the positions with reference to the ring, and of *Iapetus* and *Rhea* by reference to *Titan*. Marth pointed out that such positions of *Titan* rest on the assumption, which is not beyond doubt, that the centre of the figure of the ring coincides with the centre of the planet, and that the investigation of the orbits of the two other satellites is only possible after the motions of *Titan* have been duly determined. He points out that for a series of observations of a satellite to be made a contribution of full value towards an investigation of its motions, it is essential to adopt such a method in observing that the results of reduction may give positions of the satellite referred to the centre of the planet. In the first part of the paper he deduces the formula by which the apparent positions of the satellites referred to the planet, either by means of angular distance and position angle, or by differences of right ascension and declination, may be calculated from given elements and given places of the planet, and by which likewise the equations of condition may be found which exist between variations of the positions and corresponding variations of the elements. He then shows how to determine the approximate elliptic elements of the orbits which are to be used in the calculations, and he lastly takes into account the disturbances introduced by the action of the Sun and other bodies. This important paper, which was noticed in the Council's report for 1857 February, formed the introduction to the numerous ephemerides of satellites which he computed annually from the year 1870 to the time of his death, nearly all of which were published in the *Monthly Notices*. No further communication on the theoretical question appeared until 1887, when he sent to the *Monthly*

Notices a paper, "On the Formulæ for Computing the Apparent Positions of a Satellite and for Correcting the Assumed Element of its Orbit." He continued his researches on satellites in several smaller communications which appeared from time to time in the *Monthly Notices*, and in which he constantly urged the importance of increased observations being secured to enable him to perfect his ephemerides.

During Marth's sojourn at Durham three further important papers were communicated to the *Ast. Nach.*; the first in 1856, "Ueber die Berechnung der Coordinaten in Ellipsen von starker Excentricität"; the second in 1860, "On the Polar Distances of the Greenwich Transit Circle," which was a lengthy and stringent criticism of the Greenwich methods and reductions; the third in 1862, "Vorschlag eines neuen Verfahrens die von der Biegung eines Instruments und von den Unregelmässigkeiten seiner Zapfen erzeugten astronomischen Beobachtungsfehler zu bestimmen." This was a proposal of a new method for determining the flexure and pivot errors which was specially applicable in the case of an instrument with a prism in the centre. These proposals formed the subject of a controversy between Marth and M. Loewy which appeared in the *Monthly Notices* in 1882.

In 1862 he left Durham to join Mr. Lassell as his assistant at Malta, where the 4-foot telescope was erected. With this instrument he discovered and formed a catalogue of the positions of 600 nebulæ. Many of these nebulæ were found independently by D'Arrest and Stephan, whose observations proved the remarkable degree of accuracy with which Marth had determined positions with so unwieldy an instrument. He quitted Malta sometime in 1865, and resided in London for a few years, till 1868, when he was appointed astronomer to Mr. Newall, at Gateshead, to assist in the construction and erection of the 25-inch refractor at that observatory. This position was occupied for a few years, when Marth settled again in London, which he finally quitted in 1883 on his appcintment to Colonel Cooper's Observatory at Markree, a position that he retained for the remainder of his life. In 1882 he was sent out to Montagu Road, Cape of Good Hope, in charge of an expedition to observe the transit of *Venus* at that station. He was successful in his observations, which he considered fairly good, notwithstanding much atmospheric disturbance at the time.

Marth was a most active and accurate computer, and he well earned the gratitude of astronomers for the tables and ephemerides he regularly prepared for so many years for observations of the satellites, and for physical observations of *Mars*, *Jupiter*, and the Moon. It cannot be doubted that the assistance thus afforded to observers has been the means of considerably advancing knowledge. In the papers already cited, and in many others, Marth showed his capacity for dealing with questions of theoretical astronomy under new and original aspects. In this connection we may cite his papers "On the Computation of the Equation of the Centre in

Elliptical Orbits of Moderate Eccentricities," "On a Simple Solution of Kepler's Problem," and on "Two Auxiliary Tables for the Solution of Kepler's Problem." We may also mention the interesting paper he published in the *Monthly Notices* for 1885 March, entitled "Data for a Graphical Representation of the Solar System," the principle of which we may venture to quote. "The Sun's centre being the common focus of all the orbits, a plane passing through the Sun's centre perpendicular to the ecliptic will intersect all the orbits. Let this plane rotate, and let, for each orbit, the tracing be represented which the point of intersection produces on the plane in the course of a full rotation, and which for the present purpose may perhaps be called the 'ecliptical intersect' of the orbit. The form or shape of the tracing or intersect depends on the elements i, e, ω of the orbit: i, the inclination to the ecliptic; e, the eccentricity; and ω, the angular distance or departure of the perihelion from the ascending node ☊. A circular orbit in the plane of the ecliptic would accordingly be represented by a point or dash, a circular orbit inclined to the ecliptic by a circular arc, an eccentric orbit in which ω is $=\pm 90°$ by an arc of another curve. In order to lay down the 'ecliptical intersect' of any actual orbit, the coordinates of a sufficient number of points must be known, through which the curve may be easily drawn by hand. The coordinates required are the curtate distances from the Sun and the distances from the plane of the ecliptic, or $r \cos b$ and $r \sin b$, if r denotes the radius vector and b the latitude, to which must be added the corresponding ecliptical longitudes l and also the true anomalies ν."

Marth was never married, and gave up all family life in order to pursue his scientific studies. His aspiration had been to be able to make observations with a perfect instrument in the best climate, but his ideal was never realised, and this disappointment to his sensitive nature, coupled with indifferent health, seems to have rendered his life not too happy. He had a wide and accurate knowledge of astronomical history and a remarkable memory. An old-standing complaint, brought about by his sedentary habits, assumed an acute form while on a visit to Heidelberg, and he quietly passed away on 1897 August 6.

The honorary degree of M.A. was conferred upon him by the University of Durham. He was first elected a Fellow of the Society on 1854 May 12 and resigned in 1857; subsequently he was elected again a Fellow on 1878 January 11. E. B. K.

WILLIAM ROXBURGH was the youngest son of the late Dr. William Roxburgh, sometime Superintendent of the Botanic Gardens, Calcutta, and author of the *Flora Indica.* He was born at Calcutta on 1812 May 15. He was educated at the New Academy, Edinburgh, and afterwards entered the University of that city, where he took the degree of M.D. in 1835. In the following year he settled in London, and pursued his medical

studies at the Middlesex Hospital. He was a member of the original Council of the Royal Botanic Society of London, and took an active part in planning the gardens and in promoting the interests of that Society. In 1846 he was elected a Member of the Royal Institution of Great Britain, and formed a close friendship with the late Professor Faraday. He was for some years Physician to the Western General Dispensary, and was in 1857 admitted a Fellow of the Royal College of Physicians, London.

In consequence of a severe illness he retired from the active practice of his profession, and removed to Edinburgh in 1859. After residing there and at several places in England, he came to Ipswich in 1886, where he died on 1897 April 7.

During the last twenty years of his life he took special interest in Solar Physics. He was elected a Fellow of the Society on 1853 June 10.

Charles Stewart was born at Bo'ness, Linlithgowshire, in 1818, and died at his residence, Ackender House, Alton, Hants, 1897 September 6. For many years Dr. Stewart had a private school, from which he retired in 1889. He was elected a Fellow of the Society 1865 November 10, and was specially interested in meteors and nebulæ.

Edward James Stone was born in London on 1831 February 28. He was the elder son of Mr. Edward Stone, a member of a Devonshire family, who carried on a successful business in London. Young Stone was educated privately, but, for the benefit of his health, a large portion of his early youth was spent among his relatives in the country. His preparatory education was therefore much interrupted, his parents preferring that he should enjoy for a time the freedom of a country life, in order that his strength might be sufficiently established to enable him eventually to assist his father in his business. During these early years, young Stone, who was extremely partial to his Devonshire home, showed no indications of the innate talent he undoubtedly possessed. On his return to London, however, as his age advanced, a love of private reading was noticed, though his opportunities were very limited, for he had passed his twentieth year before he was induced to begin the study of classics or mathematics. Soon after this he was persuaded by his friends to become a student at King's College, London, and he considered that this new departure was the turning-point in his life. He has often remarked that he owed his successful career at Cambridge to the careful training he received there, especially to the Rev. T. G. Hall, who was the first to discover his latent mathematical power, and to the Rev. Dr. Major, who assisted him privately with his classics, etc.

At King's College Stone soon gave evidence of the mathematical talent that up to this time had remained dormant. He was very enthusiastic, and his progress both in classics and

mathematics was rapid. In his twenty-fourth year he entered Queens' College, Cambridge, and in 1856 he gained a scholarship. His abilities were at once recognised, and it was soon predicted by his tutors that he would take a high place in the mathematical tripos. He was, however, handicapped by occasional attacks of nervous prostration, one of which was so serious that he was unable to attend the tripos examination in 1858, thus deferring his degree for a year. In 1859 January, he graduated B.A. as Fifth Wrangler, and shortly afterwards he was elected a Fellow of Queens' College. Considering the comparatively little educational training he had had in his youth; that his higher education was not commenced until he had passed his twentieth year; that he went up to Cambridge much later in life than most freshmen; and that his health at college was never robust, his scholarship in 1856 and his high degree in mathematical honours in 1859, are somewhat remarkable examples of academic success.

It was the intention of Mr. Stone to remain at Cambridge as a resident Fellow of his college, devoting himself to the care of pupils; but on the appointment, in 1860, of the Rev. Robert Main, Chief Assistant at the Royal Observatory, to the post of Radcliffe Observer at Oxford, some of his Cambridge friends, knowing that he had shown an interest in astronomical questions, recommended him to the Astronomer Royal as a suitable person to fill the vacancy at the Observatory. His official appointment as Chief Assistant was confirmed by warrant of the Board of Admiralty on 1860 October 1. Airy, in his next annual report to the Board of Visitors, wrote:—"I have every reason to believe that Mr. Stone will well support the scientific honour of the Observatory, and its reputation for order and accuracy in the conduct of business. As First Assistant, Mr. Stone is intrusted with the fullest confidence from me, and the fullest superintendence of the Observatory in general."

When Mr. Stone first entered upon his official duties at the Royal Observatory, he was not much acquainted with the ordinary practical work required at Greenwich, but, with the help of the senior astronomical assistants, it was not long before his own personal interest in the meridian and equatorial observations became apparent, but he was only occasionally called upon to observe with any of the instruments, or to assist in the ordinary reductions of the observations. He was thus enabled to master easily the general routine business, and to undertake several original investigations, usually based on the Greenwich published results. These were not strictly official, but sometimes the subject was a special suggestion of the Astronomer Royal.

During the ten years that Mr. Stone remained at Greenwich, one of the principal astronomical questions under discussion was the importance of obtaining a new determination of the value of the constant of the Sun's horizontal mean equatorial parallax. Both Hansen and Le Verrier had found that to reconcile the observed places of the Moon and planets with the corresponding

theoretical places, it was necessary to make a considerable increase in the mean adopted value, as determined by Encke from the observations of the transit of *Venus* in 1769. Airy, who always took much interest in this problem, gave, in 1857, an oral statement at the April meeting of the Society, suggesting a redetermination of the value of this constant indirectly from comparisons of *Mars* and neighbouring stars at the oppositions of 1860 and 1862, both being particularly favourable for the purpose. Consequently, several successful series of comparisons were obtained at the principal observatories in both hemispheres. At Airy's request, Mr. Stone undertook the discussion of the observations made at Greenwich, the Cape of Good Hope, and Williamstown, near Melbourne. He entered upon this investigation with great enthusiasm, having little or no desire for extraneous help, although Airy offered any computing assistance that he might require. The resulting value was 8″·94, differing very little from the values indicated by Hansen and Le Verrier from theory, and from Winnecke's result determined from a different combination of observations of *Mars* and stars. This agreement gave Mr. Stone at the time a great confidence in the accuracy of his own calculations, and he firmly believed that his new value must be very near the true one.

A more important memoir on the same subject—"A Rediscussion of the Observations of the Transit of *Venus*, 1769"—was communicated to the Society in the autumn of 1868, and published in the *Monthly Notices*, vol. xxviii. For this paper the Council in the following January awarded the Gold Medal to Mr. Stone. It occurred to him that a new discussion of the observations of this transit might lead him to the discovery of some sources of systematic error or wrong interpretation affecting Encke's value. He was intensely interested in his own interpretations of the various phenomena of apparent and real internal contact, as inferred from the notes of the different observers, and he implicitly believed that his interpretations were correct, and that they led to a solution giving a satisfactory indication of an interval of nineteen seconds of time between the internal contact and the breaking of the black drop. His conclusions, however, were not altogether free from criticism, though he had his usual confidence in the resulting value 8″·91. He considered that this value was entitled to great weight, and was in most satisfactory agreement with those that had lately been otherwise obtained—an opinion evidently shared by the President, Admiral R. H. Manners, who, on presenting the Gold Medal to Mr. Stone, remarked that "by this important investigation Mr. Stone has earned for himself the gratitude of astronomers of all countries. He has shown beyond all doubt that the method pursued by his illustrious countryman, Halley, when fairly treated, is capable of furnishing a value of the solar parallax commensurate in precision with the expectations formed of it. But this is not all. Mr Stone, by his researches in this instance, has wiped from astro-

nomy a reproach, which did not, indeed, legitimately attach to it, but which only one of those intellectual triumphs which from time to time have adorned the annals of our science was capable of extirpating."

A reference to the *Monthly Notices* and *Memoirs* of the Society shows at once that Mr. Stone was indeed a hard worker all the time he was at Greenwich. Sometimes he had more than one investigation in hand at the same time, in addition to the daily official correspondence and other routine matters that usually devolved upon him. Some of these researches were of great importance, the results of considerable calculation, while most of the final preparation of his memoirs was performed in his leisure hours at home. His principal memoirs about this time—"On the Proper Motions of the Stars in the Greenwich Seven-Year Catalogue," "On the Sun's Mean Equatorial Horizontal Parallax from Observations of *Mars* and Stars," "On the Accuracy of the Fundamental Right Ascensions of the Greenwich Seven-Year Catalogue," "On the Constant of the Lunar Parallax," and "On the Constant of Nutation"—are all of some length, and printed in the *Memoirs*. His contributions to the *Monthly Notices* were very numerous during these ten years on almost every branch of current astronomy, including a valuable paper on "Bessel's Mean Refractions." In addition to all this work, Mr. Stone, as Honorary Secretary, took a very prominent part in the business of the Society from 1866 to 1870, and in the preparation of the annual reports of the Council for these years.

In the spring of 1870 Sir Thomas Maclear, Her Majesty's Astronomer at the Cape Observatory, resigned his office, leaving a large mass of valuable meridian observations unreduced. Mr. Stone, who was beginning to be anxious for a more independent position, became the successful candidate for the vacant post. He received official notice of his appointment early in June. He landed at Cape Town in the following October, and soon afterwards took up his residence at the Observatory. His promotion was considered a very appropriate one, though it was certainly a heavy task laid upon the new director to reduce the accumulated mass of arrears of his predecessor, and "to render these results available for the use of astronomers with as little delay as possible," as well as to continue the ordinary current work of the Observatory. Such were his official instructions on leaving England! How successfully he performed this task is now a matter of astronomical history.

The principal object Mr. Stone had in view on accepting the position of Her Majesty's Astronomer at the Cape was the formation of a standard catalogue of southern stars to about the seventh magnitude from observations made with the Cape transit-circle. He hoped to be able to publish a catalogue in which the star places would favourably compare in accuracy with those given in the Greenwich catalogues. He expected to take ten

years for the completion of this scheme. It should be remembered that Mr. Stone never had much clerical assistance during the whole time he was at the Cape, and therefore for all purposes he had to rely upon the ready co-operation of his few established assistants. Those who have had anything to do with the compilation of a standard star catalogue can understand that the preparation of the Cape Catalogue of more than 12,400 stars must have been an immense labour with so small a staff. Mr. Stone apparently worked continuously on it, occasionally assisted by Mrs. Stone, while he also took a share of the observations. He remarks in the preface to the Catalogue:—"Besides the general organisation and arrangement of the work, and the making in each year sufficient observations to check the instrumental adjustments, and the general working of the transit-circle, I have made it a rule to throw my personal weight upon any part of the work which, from time to time, appeared to flag. I have thus taken a direct share in the work to an extent which appears somewhat unusual on the part of the director of large observatories, but this was inevitable."

The reductions of this standard catalogue of 12,441 southern stars were completed, and a portion of the catalogue formed, before Mr. Stone left the Cape on 1879 May 13, but there was still a considerable amount of revision and examination requiring his attention. This, and the superintendence of the printing of the volume, occupied much of his time after his return to England. The catalogue was published in 1881, for which, in the same year, the French Académie des Sciences awarded him the Lalande astronomical prize. Soon after he commenced his residence at the Cape Observatory Mr. Stone, according to his official instructions, directed his thoughts towards completing the reductions of the meridian observations made under the direction of Sir Thomas Maclear during the years 1856 to 1860. The volume of results for 1856 was published in 1871, for 1857 and 1858 in 1872, and those for 1859 and 1860 in 1874. The general catalogue of 1159 stars derived from all these observations, reduced to the epoch 1860, was published in 1873. A second general catalogue of 2892 stars for the epoch 1840, based on Maclear's meridian observations made between 1834 and 1840, was published in 1878.

Mr. Stone was fortunate in being able to observe the total eclipse of the Sun on 1874 April 16. As the central line of shadow passed through a region not easily accessible to European astronomers, he, as their representative in South Africa, was very anxious that the eclipse should not pass away unrecorded. Accompanied by Mrs. Stone, who assisted him in the observations, he selected a station at Klipfontein, in Namaqualand. Although his instrumental equipment was limited to a 4-inch telescope, mounted as an altazimuth, and a small spectroscope, he succeeded in observing the reversal of the Fraunhofer lines at the disappearance of the Sun's limb, and in making many other important observations of the structure and composition of the

corona. The details of this expedition are given in vol. xlii. of the *Memoirs*. While in Namaqualand Mr. Stone also made a series of magnetical observations at four stations, the first made in that region of South Africa. He took no part in the many eclipse expeditions organised in England since his return from the Cape; but, at the invitation of Sir George Baden-Powell, he joined a private party on board the yacht *Otaria*, who were proceeding to Novaya Zemlya to witness the total eclipse of the Sun on 1896 August 9. The sky was fortunately clear during the totality, and Mr. Stone was one of the few astronomers who made any successful observations of this eclipse. The results were communicated to the Society in the following December, and will be published in the next volume of the *Memoirs*.

Although Mr. Stone's occupations at the Cape were absorbing, he yet found time to prepare several important memoirs, some on astronomical subjects, and others on some point in physical science. The volumes of the *Monthly Notices* give sufficient evidence of this. He also communicated to the Royal Society several papers, including results of experiments made at Greenwich on the heating power of stars; an experimental determination of the velocity of sound; magnetical observations made in Namaqualand; and on a cause for the appearance of bright lines in the spectra of irresolvable star clusters. The transit of *Venus* in 1874 was favourably observed at egress by Mr. Stone and his assistants at the Cape Observatory.

After the publication in 1877 of the official report on the observations of the transit of *Venus* in 1874, drawn up under the supervision of Sir George Airy, from which a mean solar parallax of $8''\cdot76$ was deduced, Mr. Stone made a rediscussion of the various observations of contact, in accordance with his own particular views on the subject. He obtained a mean parallax of $8''\cdot89$ from his interpretation of the contact observations, and he states that his result absolutely negatived any value smaller than $8''\cdot84$, or larger than $8''\cdot93$.

The Rev. R. Main, Radcliffe Observer, died in the spring of 1878, and towards the end of the year Mr. Stone was appointed by the Radcliffe Trustees to succeed him. He, however, was not able to take up his residence at Oxford before the end of 1879 June, but Professor Pritchard had the general charge of the Observatory in the meantime. Mr. Stone was very gratified at this appointment, especially as it enabled him to renew his association with former astronomical friends, and with the proceedings of the Society.

Mr. Stone was a member of the Transit of *Venus* Committee appointed by the Royal Society to advise upon the conduct of the observations to be made in the transit of 1882, and also of the Executive Committee, on which he acted as the directing astronomer of the arrangements. He was intrusted with the general superintendence of the preliminary training of the observers at the Radcliffe Observatory, and of the instrumental equipment of

the different stations. After the transit he undertook, with the assistance of a special computer, all the reductions, and also the discussion of all the observations of the various phases of external and internal contact. The interpretation of the true meaning of the notes of the observers entailed a considerable personal labour on Mr. Stone; but eventually he determined the value of mean solar parallax from this transit to be $8''\cdot832$. The final report of the Government Committee was drawn up by Mr. Stone, and published in 1887 by order of the House of Commons.

While at Oxford Mr. Stone usually controlled the daily work of the Observatory, devoting much personal attention to the supervision of the reductions, but he took no active share in the ordinary observations. In the autumn of 1888, however, he made a special series of heliometer observations of the minor planet *Iris* with comparison stars, in accordance with a scheme of combined operations proposed by Dr. Gill, for a new determination of the value of the constant of solar parallax. He entered upon this duty with great energy, although the watches were long and wearying, extending generally to about 2 A.M. He took much interest in these observations, hoping to make the series as complete as possible; but though he obtained several sets of comparisons, the Oxford variable climate prevented him from making it as perfect as he had wished. In the following year Mr. Stone also made several attempts to observe the minor planets *Victoria* and *Sappho*, for the same purpose; but owing to the faintness of the planets and broken weather, no satisfactory observations were made.

The Radcliffe Catalogue of 6424 stars for the epoch 1890, published in 1894, is a valuable work, and a most important contribution to sidereal astronomy. This catalogue contains the positions of all the stars to the seventh magnitude, from the equator to 115° N.P.D., excepting those in clusters, observed with the transit-circle during the years 1880 to 1893. The positions of some fainter stars to fill existing lacunæ, and of a few others observed beyond the adopted limits for some special purpose, are also included in the catalogue. This important work may be considered as the continuation and completion of the original plan of operations commenced at the Cape Observatory in 1870, and there can be no doubt that upon Mr. Stone's two noble standard star catalogues his reputation as a practical astronomer will principally rest.

The Royal Society "Catalogue of Scientific Papers" to 1883 contains the titles of ninety-two separate papers by Mr. Stone. About sixty more were communicated by him to the Royal Astronomical Society between 1884 and 1897. Many of these are of great interest, but the limited space at our disposal forbids any special reference to them here. The titles may be easily found in the various indexes to the *Monthly Notices*. The long series of controversial papers on a supposed change in the adopted length of the mean solar day ought not, however, to be passed over without some brief

notice, as this was a question that largely occupied his attention during the last fourteen years of his life. On 1883 May 11, he communicated to the Society a paper stating that he had discovered the principal cause of the large errors existing between the positions of the Moon deduced from Hansen's Lunar Tables and observation. He attributed these increasing tabular errors to a change in the unit of time, caused by the adoption in 1864 of Le Verrier's expression for the sidereal time at mean noon instead of that of Bessel, which had been previously in use in the calculations of the *Nautical Almanac*. Mr. Stone contended that in consequence of this change of formulæ in the *Nautical Almanac* calculations of the sidereal time at Greenwich mean noon, the unit of mean solar time was practically altered to such an extent that at the end of 1881 the difference amounted to nearly twenty-seven seconds, increasing at the rate of about $1^s{\cdot}46$ per annum. This explanation was given by Mr. Stone with much confidence in its accuracy, but Professors Adams and Cayley at once pointed out in the clearest and simplest manner that this view of Mr. Stone was erroneous, and that the true rate of increase per annum was only 1-365th part of that amount, or $0^s{\cdot}004$. However, notwithstanding the expressed opinions of these and several other leading mathematical astronomers, it is remarkable that he sincerely and firmly believed that his theory was correct, and that the substitution in 1864 of Le Verrier's Solar Tables for those of Carlini fully accounted for the increasing errors of Hansen's Lunar Tables, even after his attention had been specially drawn to the point where his reasoning was shown to fail. So strong was he in this belief, that he was never able to perceive, or to acknowledge in any way, that his arguments could possibly be unsound, though it had been practically proved by calculation that whether Le Verrier's or Carlini's Tables were used to compute the sidereal times at mean noon, the tabular errors of Hansen's Tables would be substantially the same. On the contrary, he continued year after year to carry on the controversy with excellent temper, defending his conclusions with great earnestness and pertinacity, due in some measure to his naturally sensitive disposition.

Mr. Stone was elected a Fellow of the Society on 1861 January 11. He at once took an active share in the discussions at the meetings. He was a member of the Council from 1863 to 1870, and again from 1880 to 1897; Honorary Secretary from 1866 to 1870; and President, 1882–84. During his Presidency he presented the Gold Medal of the Society to Dr. B. A. Gould in 1883, and to Dr. A. A. Common in 1884, after delivering an appropriate address on each occasion. He was elected a Fellow of the Royal Society in 1868, and he served two years on the Council, 1881–83. He was an Honorary Fellow of Queens' College, Cambridge; M.A. (Cantab. et Oxon.); a Member of the Board of Visitors of the Royal Observatory, and of the Meteorological Council; an Honorary Doctor of Natural Philosophy in the University of Padua; a Corresponding Member of the Société

Nationale des Sciences Naturelles et Mathématiques at Cherbourg; and an Honorary Member of the Literary and Philosophical Society of Manchester.

From his youth Mr. Stone was very fond of fly-fishing and shooting. When resident at Greenwich and Oxford, he generally spent a portion of his holidays every year in these pursuits. He was accustomed to say that his fishing expeditions on the Irish and Scottish rivers were to him the most agreeable outdoor recreation, taking away all his thoughts from observatory work, and even from astronomy itself. Only a week before his death he was on a fly-fishing excursion in North Wales, and had had a slight accident by the upsetting of his boat. Hoping to avoid a chill, he rowed quickly back to the hotel, a distance of about two miles. In doing this he apparently overstrained his heart. About three days after his return to Oxford pneumonia set in, though he was able on the day preceding his death to spend some time in the Observatory, selecting a site for setting up some instruments for trial preliminary to his proposed journey to India to observe the total solar eclipse on 1898 January 22. On the same night he became much worse, but there was then no suspicion that he was in immediate danger. The end, however, came very suddenly, from cardiac failure, shortly before noon on Sunday, 1897 May 9, when he quietly passed away in the sixty-seventh year of his age.

By the almost sudden death of Mr. Stone, the Society has been deprived of one of the most devoted of its members. He was rarely absent from the Council table or at the ordinary meetings, where his well-known face will in future be sadly missed. It has been truly said that when joining in any discussion in which he felt a personal interest, "the brightness of his eyes, and the rapidity of his utterance, revealed the earnestness and energy of his spirit." Though he was ever ready to enter into an animated debate to defend his own conclusions, he was always genial, even when he differed strongly from others on some controversial point, while at the same time those who did not agree with his opinions usually respected the conviction with which he apparently held them. He has been known to spend hours writing and re-writing paragraphs stating his special views on astronomical questions, so as to avoid giving offence to anyone, though occasionally he felt that he must write plainly. The writer, looking back to his ten years of close official and private association with Mr. Stone at Greenwich, is able to recall to his mind many instances of this marked feature in the defence of his own opinions, and in his criticisms of another's work, as well as some most pleasing reminiscences of his assistance and kindness in many ways.

On 1866 September 12 Mr. Stone married a Devonshire lady, Grace, daughter of Mr. John Tuckett, by whom he leaves one son and three daughters.

E. D.

WILLIAM REYNOLDS VINES was born in Bristol in 1817. He began life as a Moravian missionary, and served in Jamaica for some years, until he was invalided home. He eventually established a large and successful school at Elm Grove, Ealing, but was obliged to give it up in 1863 on account of ill-health. He had married in 1847, and had one son (now Sherardian Professor of Botany at Oxford). From 1863 onwards he travelled a great deal, but ultimately settled in 1889 at Auckland, New Zealand, where he died on 1897 November 16. He was elected a Fellow of the Society on 1855 April 13.

CHARLES CLEMENT WALKER was born in Clerkenwell in 1822, and was educated in London. He served his apprenticeship as a marine engineer, and later joined his brother, the late Mr. William Walker, in the construction of gas-work machinery, first in Clerkenwell and afterwards at Donnington. The business prospered greatly under the management of the brothers, and the works at Donnington now find employment for some 700 men. The firm have carried out some of the largest structures for the purification and storage of gas in this country and abroad. Mr. Walker was liberal in devoting his wealth to public and charitable objects—as, for instance, in the laying out of Wilmington Square and Northampton Square, in Clerkenwell.

Mr. Walker was one of the oldest readers at the British Museum, having obtained a reading-ticket at the age of 18, and scarcely ever missed an opportunity of visiting the Museum when he came to London. He had a telescope at his residence, Lilleshall Old Hall, and astronomy was his favourite study.

He died on 1897 February 4, from pneumonia and prostration following a severe attack of influenza.

He was elected a Fellow of the Society on 1879 March 14.

WILHELM DÖLLEN was born at Mitau, 1820 April 25. He there received his earliest instruction, chiefly from his father, who was principal of an excellent school; and at a very early age the exceptional ability of the boy, especially for mathematics, was made manifest. When he was 14 years old, his whole family removed to Dorpat, where he was introduced to the celebrated mathematician Bartels, who soon satisfied himself of Döllen's powers, and advised him, notwithstanding his youth, to attend the mathematical lectures at the University in the following year. From 1836 onwards Döllen also attended the astronomical lectures of W. Struve, with whom and whose family he, from this time, remained on the most intimate terms. According to the statutes Döllen could only be received as a student in the University in the summer of 1837, on attaining the age of 17, but he completed his course in the spring of 1839, and gained his degree with honours in mathematics. Immediately after this he was appointed assistant in the Dorpat Observatory, and remained for five years in that capacity, during which time he

undertook to carry to completion the determinations of positions of double stars by means of the meridian circle, which work had hitherto been carried on by W. Struve and Preuss. The result of this labour was published at a later date in one of the volumes of the Dorpat Observations, and forms an important part of W. Struve's well-known *Stellarum compositarum Positiones mediæ*. To this lengthened stay in Dorpat Döllen was especially indebted for that thorough acquaintance with all departments of human knowledge which distinguished him in later life.

In the spring of 1844 Döllen was appointed supernumerary assistant at the Observatory of Pulkowa. In this capacity he took a most zealous share in the great chronometer expedition between Altona and Greenwich, by which the longitudes of Continental observatories from Greenwich were ascertained for the first time with a fair amount of precision. Döllen gratefully remembered for the rest of his life the kindly courtesy and helpful advice of Airy during his long stay at the Royal Observatory, Greenwich. Three years later, in 1847, a vacancy occurred for an assistant at the Pulkowa Observatory, and Döllen was formally appointed. In this position (excepting only that he was subsequently promoted to the rank of Älter-Astronom) Döllen remained without interruption until the year 1890. Several times during this long period of time he acted as Director, during the latter's absence from illness or other causes.

The first of Döllen's own individual work, which had for its title "Neue Reduction der Königsberger Declinationen für 1820," appeared in 1849 in the *Memoirs* of the St. Petersburg Academy of Sciences. Some years previously he had been attracted by the then little regarded suggestions of Gauss for map-projections, and had constructed, not only convenient formulæ, but tables for their practical application. In consequence of this work, the Gaussian method of projections was in 1847, at the suggestion of W. Struve, introduced into all the cartographical work of the Russian General Staff. Some special researches of Döllen were published by him in 1853 in a separate work, under the title of *Meletemata de Methodis secundum quas superficies delineantur*. In the same year (1853) there appeared Döllen's well-known discussion, in the *Bulletin* of the St. Petersburg Academy, under the title, "Ueber Dr. Wichmann's Bestimmung der Parallaxe des Argelander'schen Sterns (Gr. 1830)," which excited general attention, not only by its sharp criticism of the above-mentioned determination, but also by its comprehensive and searching discussion of the sources of error in observations made with the heliometer. This discussion, moreover, was of the highest value in urging on those improvements in the construction and use of the heliometer by which this instrument has attained its present position as the finest astronomical instrument of precision.

In 1855 Döllen was appointed Professor of Geodesy and

Surveying, his students being the military and marine officers who spent the regulation two years in these studies at Pulkowa. This position not only afforded him an opportunity of exercising his exceptional powers as a teacher (so that we have him to thank for the series of splendidly trained geodesists who, during the decades 1860–90, conducted the geodetic and geographical work of Russia, and brought it to so high a degree of perfection), but also drew his special attention to researches on the methods of observation employed and the construction of the instruments to be used in the work. Amongst his numerous contributions to this subject, the two most important papers appeared in 1863 and 1874, under the title of *Die Zeitbestimmung vermittelst des tragbaren Durchgangsinstruments im Verticale des Polarsterns*, which have made this excellent method for the determination of time widely known and adopted in practice. His work in this direction has been completed by the Ephemerides which he regularly computed and published from 1886 till the time of his death.

It was only in the first few years that Döllen took an active part in the special astronomical observations at the Observatory of Pulkowa. So early as the autumn of 1850 he had a severe attack of typhus fever on which pneumonia supervened. His strong constitution carried him through the sickness, but during the rest of his life he was subject to chronic lung trouble, which necessitated his taking the greatest care to avoid catching cold, to which the observing astronomer is so liable. Before this he had made observations with the Repsold Meridian Circle for the completion of the Pulkowa Catalogue (Epoch 1845) of all stars down to the 6th magnitude. Later he carried on the fundamental determinations of declination with the great Vertical Circle; but he soon found it necessary to discontinue the work, his weak health compelling him to give up night work. He accordingly occupied himself the more zealously in day observations with portable instruments, in order to examine and develop the various methods of observation for the purpose of determining geographical position. These studies naturally gave him various ideas for improving the construction of the instruments used in this kind of work, which have been duly regarded by the best instrument makers, particularly the Repsolds.

By the advice of his physician, Döllen on two occasions passed the winter in Africa—in Algeria during 1866, and in 1874 in Egypt. These two journeys at the same time afforded him an opportunity of observing the transit of *Venus* at Thebes, in company with Professor Auwers, and of working jointly with Dr. Gill at the geography of those regions.

Soon after Otto Struve left Pulkowa, in the beginning of 1890, Döllen retired completely into private life, and chose for his abode Dorpat, the spot he had loved from early youth. Even here, although freed from all official obligations, he could not be idle. He was especially desirous of assisting in the further

development of nautical astronomy, which science has scarcely made any progress, beyond improvements in the chronometer and compass observations, during the course of the present century, whilst the extraordinary increase in navigation evidently demands more exact determinations of a ship's place at sea than the methods previously in use. With this object in view, in 1893 Döllen published an appeal for assistance in his endeavour, and only a few weeks before his death he published a pamphlet under the title "Zur Reform der Nautischen Astronomie, Tabulæ Dorpatenses," with convenient formulæ based on Sumner's method, and gave the requisite tables calculated for a determinate latitude (58°–59°).

In the foregoing notice only the most important of Döllen's publications have been mentioned. He displayed his greatest activity indirectly as a teacher and a critic of the work of others. During his forty-five years of official life at Pulkowa almost all the work of the Observatory was influenced by his spirit and his extensive knowledge. He was the general arbiter in scientific questions. In such ways as these he essentially contributed to the prosperity of the Pulkowa Observatory under the directorship of the two Struves.

Döllen in 1848 married Charlotte, the eldest daughter of W. Struve, and spent with her forty-six years of happy married life until the time of her death in 1894.

After his retirement from official work, in 1890, it became clear that there was not only lung-trouble but weakness and ossification of the heart, which eventually brought on his death, 1897 February 16.

He was elected an Associate of the Society on 1882 November 10.

Friedrich August Theodor Winnecke was born on 1835 February 5, at the village of Gross-Heere, near Hildesheim, in Hanover, where his father was pastor. A few days after his birth his mother died, and the charge of the child devolved upon his two aunts. His father, who suffered so keenly the sudden death of his wife, resigned his parsonage after a few years. At the age of five young Winnecke was established in the home of his relations at Gittelde, in the Hartz, and later on at Hoya, where he was educated at the Gymnasium till 1850, when he went to the Lyceum at Hanover. Leaving that school when he was eighteen, he entered the University of Göttingen, and devoted himself to astronomical and mathematical studies. He had already shown great inclination in that direction while at school at Hanover by diligently observing the heavens with such small instruments as were available. At Göttingen, in company with Pape, he made observations of comets with a comet-seeker of 34 lines aperture, and determined their places with a ring micrometer. It is interesting to note that at Göttingen Winnecke aroused the enthusiasm for astronomy of the present Professor

Auwers, who was then a pupil at the Gymnasium. The illustrious Gauss, who, on account of old age, had ceased delivering lectures, took great interest in the young and capable student at the University, and it was he who sent Winnecke's first communications to the *Astronomische Nachrichten*.

In the autumn of 1854 Winnecke went to the Berlin University, where in 1856 August he took his degree as Doctor of Philosophy. His dissertation, dedicated to Encke, was entitled "De stella η *Coronæ Borealis* duplici"—a work which at once showed at this early age his sound knowledge of theoretical and practical astronomy.

In this period of his academical career he displayed very great devotion to his studies, observing and computing night and day, while attending the University lectures and elaborating his dissertation, to which the volumes 38–44 of the *Ast. Nach.* bear witness; and his capacity for work is well shown by his determination of the diameter of *Mars* with the heliometer, and his double-star observations with the 9-inch refractor.

Attracted by the fame of that great master of practical astronomy, Argelander, Winnecke in 1856 November went to the Bonn Observatory, where he was most favourably received. Here he remained till 1858 May, displaying throughout that time great and versatile activity, recorded in his papers in vols. 45–48 of the *Ast. Nach.* The 6-inch heliometer had been used up to that time as a telescope with an undivided object-glass. Winnecke investigated it as Bessel had done with the Königsberg heliometer, and he made an extensive series of measures of the principal stars in the cluster *Præsepe*, and with it he also determined the parallax of the star *Ll.* 21185, and of the nebula *h.* 2241. Besides this, he was intent on observing comets, and it was at Bonn that he discovered a periodical comet. He also devoted much attention to variable stars, his interest in which had been excited by the fascinating influence of Argelander.

That period of successful labour, which in after years he looked back upon with so much satisfaction, did not last very long. Wilhelm Struve was a master in discovering men whose intellectual capacity fitted them for attacking certain problems. On his visit to Bonn in the autumn of 1857 he soon perceived the great advantage it would be to the Pulkowa Observatory to have the co-operation of Winnecke, and the invitation he made to him to come to Pulkowa, which was a great honour, was accepted by Winnecke, and accordingly in 1858 May he quitted Bonn. In a short time he advanced from the position of an assistant to that of senior astronomer, and finally to the position of Vice-Director of the observatory.

At Pulkowa his great industry in using the refined instruments of that observatory was unprecedented, and exercised an immense influence not only upon the staff but upon all astronomers who visited the observatory. The Repsold Meridian Circle engaged most of his attention, and the observations he

made with it, extending from 1858 September to 1864 October, form a large part of the first Pulkowa General Catalogue of Stars.

In order to test the accuracy of Encke's value of the solar parallax, determined nearly forty years previously, Winnecke proposed in 1862 an elaborate programme for meridian circle observations of *Mars* at the approaching opposition, which was successfully carried out; and by combining the Cape observations with his own he arrived at a value of 8″·964 for this constant, proving that Encke's value was too small.

Winnecke's careful investigations on the nature of the great comets of 1858 and 1862 with the 7-inch heliometer and the 15-inch refractor are well known. Many observations of comets, nebulæ, and variable stars made by him in this period will be found in vols. 49–60 of the *Ast. Nach.* In 1864 he temporarily undertook the Directorship of the Pulkowa Observatory during the serious illness of the Director, Otto Struve. It was during this period also that he entered into friendly relations with many English astronomers, especially with Sir George Airy, and he was a member of the Himalaya eclipse party which went to Spain in 1860. In 1864 he paid a second visit to Greenwich for the purpose of examining the old Bradley instruments and MSS.

In 1864 May Winnecke married the niece of Otto Struve. But soon a cloud overshadowed the happiness of his married life. He began to feel the effects of an illness contracted on a voyage, and of over excitement, produced partly by the excessive mental strain of the previous ten years, partly by the weight of responsibility on one so young in the extensive administration of a large observatory, and perhaps also by an attack of acute terror experienced when working one night with the meridian circle. Finding it in vain to obtain recovery from visits to various health resorts, he, in 1865, sent in his resignation, and placed himself under the treatment of Dr. Hertz, at Bonn, where, by the year 1867, his health was completely restored. He now established himself at Carlsruhe with his wife's relations, and by degrees was able to resume some astronomical work. The Grand Duke Frederick of Baden graciously granted him the use of an observatory in the Erbprinzen Garten, and he had some rooms in the small castle, where he was able to observe with some small instruments. Later on he took part in the preparations for the transit of Venus expeditions.

Satisfied with his work, and encouraged by the prospect of renewed happiness, his health greatly improved, so much so that in 1872 he was called to Strasburg to fill a professor's chair and to establish the new observatory that was proposed to be founded there. His old activity at once returned, and he worked hard at elaborating his proposals for the erection of the observatory. He was also much occupied in training astronomers in the necessary investigation of the four heliometers which were to be employed at the forthcoming transit of Venus in 1874.

Eminent as he was in research, he displayed now an equal mastery in the art of teaching. His excellent methodic lectures on astronomy at the university, and his instructive scientific discussions, were most inspiring, ever suggesting independent working in theoretical researches, and in the practical use of instruments. Though he was heart and soul an observer, his mathematical ability made him a master in theoretical investigation, which he enunciated clearly and tersely. His enthusiasm for astronomy, and his unrelaxing energy in utilising every available hour of the night when the sky was clear, made him a conspicuous example to inspire and imitate. With all his superiority and scientific eminence and many-sided knowledge, he was gifted with refined modesty. If asked a difficult question, he requested a short time to consider it, and to consult the literature of the subject, with which he had an extraordinary acquaintance, and then he always delivered an exhaustive explanation.

In 1880 the new observatory, furnished with the largest and best instruments, and admirably constructed in every way, was finished, and in November of that year he was installed. In this year Winnecke was invited to fill the professor's chair for astronomy and to direct the observatory at the Munich University, as successor to Lamont, but the Government induced him to decline it.

The preliminary work for the various proposed investigations at Strasburg was commenced, when in 1881 January 13 he was plunged into affliction by the death of his eldest child, a highly capable and amiable boy. It might be that the absorbing interest of completing the observatory before the meeting of the Astronomische Gesellschaft at Strasburg, which was fixed for 1881 September, and which he accomplished with so much success, kept him up, and thus delayed the sad catastrophe dreaded by his friends; nevertheless in 1882 January, just when his colleagues had elected him rector of the university, and a year after the sad death of his child, the melancholy power again took possession of him. He resolved immediately to put himself under the care of Dr. Hertz at Bonn, hoping, like his family and friends, that the sympathetic treatment of that experienced physician might be able to ward off once more his impending fate. Unhappily all treatment was unavailing, and darkness settled on his great mind uninterruptedly for sixteen years, till 1897 December 2, when he peacefully died.

By his numerous important investigations in various branches of astronomy, published in the *Astronomische Nachrichten*; in the *Monthly Notices*; in the *Vierteljahrsschrift der Astronomischen Gesellschaft*; in the *Bulletin* and *Mémoires de l'Académie de St.-Pétersbourg*; and in the Pulkowa publications; and by the erection and establishing of the Strasburg Observatory, Winnecke has founded a permanent memorial of his illustrious place as an astronomer.

As he was many-sided in astronomy, so he was well acquainted with other branches of natural science, especially geology and mineralogy, in which he took great interest and worked at practically. His versatility and his humour made him a most genial companion. His love of truth, his loyalty, and the gentleness of his mind made him a highly esteemed and beloved friend; and his trustworthy judgment and extensive knowledge contributed to his excellence as a teacher and a scientific man.

He was elected an Associate of the Society 1863 November 13.

[The council is indebted to Dr. Ernst Hartwig for this notice.]

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same :—

Royal Observatory, Greenwich.

With the transit circle 11,416 observations of transits and 10,614 of zenith distances were made in 1896. The total number of stars observed is 5047. About 4000 of these stars are within 26° of the pole and are the reference stars for the Astrographic Catalogue. The remaining observations were of planets, Moon culminators, or for determination of clock error, azimuth, zenith point, &c.

The Moon was observed 103 times with the transit-circle; the mean error in R.A. of Hansen's *Lunar* Tables with Newcomb's corrections as deduced from these observations is $-0^{s}\cdot154$. The errors for the years 1883–97 are as follows :—

	s		s		s
1883	+0·031	1888	+0·090	1893	+0·034
1884	+0·018	1889	+0·010	1894	−0·016
1885	+0·024	1890	+0·020	1895	−0·066
1886	+0·029	1891	+0·079	1896	−0·088
1887	+0·059	1892	+0·083	1897	−0·154

The number of reflexion and direct observations of zenith distance of stars made during the year was 525. The apparent correction to the *Nadir* observation deduced from these is $-0''\cdot27$. For the years 1890 to 1897 the corrections are $+0''\cdot08$, $+0''\cdot07$, $-0''\cdot25$, $-0''\cdot34$, $-0''\cdot27$, $-0''\cdot26$, $-0''\cdot34$, and $-0''\cdot27$. As stated in last year's report, the screw of the telescope-micrometer was found to be worn and observations were made in January to determine the amount of wear. The intervals of the screw $12^{r}-20^{r}$, $16^{r}-24^{r}$, and $20^{r}-28^{r}$, were compared with $5'$ on the circle, which is approximately 8 rev. of the screw. Further, the intervals $12^{r}-16^{r}$, $16^{r}-20^{r}$, $20^{r}-24^{r}$, $24^{r}-28^{r}$ were compared with

a definite length on the south collinator; the intervals 16^r-18^r, 18^r-20^r, 20^r-22^r, 22^r-24^r, were similarly compared; the single revolutions from 16^r-24^r, were similarly compared. The combination of these observations gave the following corrections to be applied to the adopted equivalents of the readings of the screw:—

12^r	16^r	17^r	18^r	19^r	20^r	21^r	22^r	23^r	24^r	28^r
$+1''.39$	$+0''.80$	$+0''.52$	$+0''.35$	$+0''.16$	$0''.00$	$+0''.02$	$+0''.07$	$+0''.20$	$+0''.32$	$+1''.10$

These corrections were applied to the observations made in 1896 whenever the correction amounted to $0''.10$, and to all the observations of 1897.

The application of these corrections reduced the discordance of the *Nadir* observations for 1896 from $-0''.43$ reported last year to $-0''.34$ given above.

Since the middle of 1895 July, three observations of the *Nadir* have been made on a large number of days. Grouping the observations according to the time of day at which they were taken, the following changes of zenith point are shown :—

	9h–15h.	15h–21h.	21h–3h.
	$''$	$''$	$''$
1895	+0.29	0.00	+0.27
1896	+0.20	0.00	+0.16
1897	+0.15	0.00	+0.17

The R—D discordance for the year is much smaller than it has been for many years. The series of observations of zenith distances of pairs of stars in which one star is observed directly and the other by reflexion alternately on alternate nights has been continued, and forty-three pairs have been observed during the year.

Considerable progress has been made with the ten-year catalogue for 1890. The observations have all been entered from the ledgers for different years on separate sheets for each star, and the precessions and secular variations have been computed and applied. In addition the means have been taken and the catalogue place for 1890 deduced for the clock stars and for 632 *Berliner Jahrbuch* stars which were requested by Dr. Auwers for use in the formation of a fundamental catalogue on which he is engaged.

With the altazimuth forty-three observations of the Moon in the first and last quarters were made during the year.

The new altazimuth when first erected showed anomalous circle readings depending on the direction in which the instrument was last turned. Experiments made under Mr. Simms' direction indicated flexure of the axis, this was corrected by the insertion of a diaphragm in the central part of the instrument. The method of relieving the weight of the instrument was also changed. Instead of friction rollers resting on springs which

pushed the instrument upwards, live rings were put round the axis near the pivots, and these are fastened to springs which tend to pull the instrument upwards. The discordances in the microscope-readings have been almost entirely removed by these means, but there still remains a small difference in the readings of the two circles when the instrument is moved by the slow motion, which is near one end of the axis and appears to produce a slight torsion of one circle relatively to the other.

A few trial observations have been made with the instrument, and the determination of the division errors is in progress.

Comet *Perrine* (1897, *b*) was observed on five nights with the Sheepshanks equatorial. Forty-nine occultations of stars by the Moon were observed by one or more observers, and thirteen phenomena of *Jupiter's* satellites.

With the 28-inch refractor measures were made of distance and position angle of 232 double stars. In all, 492 sets of measures were made, all the observations of one star on a single night constituting one set. Of these stars 72 were less than 0″·5 apart, 61 between 0″·5 and 1″·0, 154 between 1″·0 and 2′·0, and 40 larger than 2″·0. A good series of measures of 70 *Ophiuchi* was obtained, and the following especially interesting pairs which were measured may be noticed :—

	Mags.		Dist.		Mags.		Dist.
			″				″
β 524	5·5	6·5	0·1	ζ *Herculis*	2	6	0·5
β 878	5·8	13·7	1·1	Σ 2525	8	8	0·4
β 883	7·5	7·8	0·3	ζ *Sagittæ*	5	6	0·2
β 552	6·9	10·2	0·4	τ *Cygni*	4	10	0·6
Σ 1639	6·5	8·0	0·2	κ *Pegasi*	4·3	5·0	0·1
Σ 1728	6·0	6·0	0·1	β 733	6	11	0·6

The distance and position angle of the satellite of *Neptune* have been measured on nine nights. The crown lens of the object-glass was reversed from January 12 to April 23, and photographs of the Moon and of the double stars *Castor*, ξ *Ursæ Majoris*, γ *Leonis*, Σ 1606, ζ *Cancri*, and Σ 1877 were obtained.

The erection of the Thompson equatorial was completed in April. The adjustment of the polar axis of the instrument was made at once. Photographs were taken with different separations of the lenses, but it was found that there was a coma in the lateral pencils which could not be got rid of. These photographs were sent to Sir Howard Grubb, who considered it necessary to have the lenses back at Dublin in order to refigure some of the surfaces. Before the object glass was returned some photos of the Moon and double stars were obtained, both in the principal focus and with an enlarging lens. The 30-inch Cassegrain mounted on the other end of the declination axis has been adjusted, and some photographs of the Moon and a few star fields

obtained. The spectroscope has been mounted, but no observations made with it as yet.

With the astrographic equatorial 473 plates with 769 exposures were taken on 117 nights. Of these 91 have been rejected—viz. 27 because the exposure was interrupted by cloud, 18 because the plates did not come up to the standard in showing faint stars, or were too dark for measurement, 24 owing to bad guiding, 18 from miscellaneous defects in the observing or development, and 4 owing to bad plates. Of the 382 successful plates, 248 are for the chart, 120 for the catalogue, 9 typical areas, and 5 for the adjustment of the instrument.

The following table shows the progress of the photo-mapping of the heavens to the end of 1897 :—

	Catalogue.	Chart.
Number of successful fields on 1896 Dec. 31	769	484
Number of successful fields taken in 1897	113	248
Number previously passed, rejected in 1897	8	5
Number of successful fields 1897 Dec. 31	874	727
Total number still required	275	422

Positives on glass of 181 chart plates were made during the year, which with the 358 reported last year, gives a total of 539 plates of which copies on glass have been taken.

During the year 198 plates have been measured, 16 in the direct and 182 in the reversed position in the micrometer. All the plates whose centres are at declination 65°, 66°, and 67°, and the southern halves of those whose centres are at declination 68°, have now been measured in the direct and reversed positions of the plates. The 6^m and 3^m images of each star are measured twice on each plate, so that the positions of the stars generally depend on eight measures, that is, two measures of each image on two plates. Altogether 268 plates have been completely measured.

The measures from 64° to 67° N. declination have been discussed for the personality of measurement. These show that this may amount to about $0''\cdot3$, and that it is almost entirely eliminated in the mean of the direct and reversed measures if made by the same observer.

Copy for press of the measures for zones 65° and 66° has been made, and that for zones 64° and 67° is in progress.

The total number of stars measured in the different zones compared with the number in the B.D. and the A.G.C. are approximately :—

Zone.	No. of Stars. Shown on Plates.	No. in B. D.	No. in A. G. C. Cat.
64°	9100	1900	1200 (Helsingfors)
65	8800	2001	844 (Christiania)
66	8600	1684	745 ,,
67	8600	1285	574 ,,

O 2

The average number of stars per square degree measured on the plates is 60.

Photographs of the Sun were obtained with the Dallmeyer photoheliograph of 4 inches aperture on 203 days. Of these 409 have been selected for preservation, including 8 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1897 October 27, and from Mauritius up to 1897 August 25, leaving only one day, 1897 February 5, for which no photograph is available for measurement in the year ending with the date of the last Mauritius negative received.

The Greenwich photographs have been measured in duplicate up to 1897 December 2, and the Indian and Mauritius photographs so far as they have been received, with the exception of fourteen Indian photographs. The areas and heliographic positions of the spots and faculæ have been computed very nearly as far as the measurement extends. The copy for press of the daily results is complete for about nine months of the year, except that the spot groups have not been numbered beyond the middle of May. The computations for the ledger are complete as far as 1897 February 14.

The mean daily spotted area of the Sun for 1896, expressed as usual in millionths of the visible hemisphere, is 543, as compared with 974 for 1895, 1282 for 1894, 1464 for 1893, the year of maximum. A rough estimate for 1897 gives 535 for the mean daily spotted area for the year, showing only a very slight difference from the preceding year.

The sun was free from spots on 17 days, and free from faculæ on 6 days, so far as the record is as yet complete. There was a well marked minimum in May and June, the Sun being free from spots for a whole week, May 13–19 inclusive.

The volume of the *Greenwich Observations* for 1895 is printed, with the exception of the Introduction, of which proofs have been received and returned to the printers. The transits, zenith distances and daily Sun-spot results have been printed for 1896.

The north wing of the new Physical Observatory has been occupied since May. Progress is being made with the building of the east and west wings. The electric light is being introduced into the new building. Arrangements have been made for the extension of the telephone from the magnet house to the new building.

Mr. Furner was appointed an Established Computer in November.

The Astronomer Royal left for India on December 13, and Mr. Maunder left on December 8 to observe the total eclipse of the Sun of 1898 January 22.

Royal Observatory, Edinburgh.

The time service, including the daily dropping of the time ball on the Nelson Monument and the firing of the time guns at Edinburgh Castle and at Dundee, as well as the control of several public clocks in the city of Edinburgh, has been carried on, as in former years, under Mr. Heath's charge, the standard mean time clock by Molyneux having been used for this purpose since the removal of the Observatory to Blackford Hill. The observations of time stars have been made with the Dunecht Meridian Circle throughout the year, the satisfactory completion of the roof shutters having admitted of this instrument being brought into regular use in the end of 1896. The 4-inch reversing transit instrument, formerly used for time observations, was dismounted in October.

The clock chamber in the base of the east tower still continues to give some trouble, owing to the escape of moisture from the cement. The Brisbane standard sidereal clock by Dent, being inclosed in an air-tight case, fortunately suffers nothing from this cause. It has been found advisable, however, to dismount the Frodsham clock and temporarily remove it from the chamber. The exposure of calcium chloride in shallow pans is still continued, and the amount of moisture removed in this way appears to be slowly lessening, thus giving some hope that this difficulty will be overcome in time.

The meteorological readings, commenced on 1896 January 1 and fully detailed in the report on the work of that year (*Monthly Notices*, vol. lvii. p. 239), have been regularly carried on. In addition a pair of maximum and minimum exposed black-bulb thermometers were placed in position on 1897 January 1, and have since been read daily. As usual, copies of the daily readings have been supplied to the Scottish Meteorological Society, and abstracts of them are printed in the returns of the Registrar-General for Scotland.

The new reduction of the right ascensions of the stars observed under the direction of the late Professor Henderson has made considerable progress, and continues to show evidence of a satisfactory final result being arrived at.

The bifilar pendulum, with its photographic apparatus for recording earth tremors by the rotation of a suspended mirror, has worked with much regularity throughout the year, the record being nearly continuous. The most remarkable result yet obtained with this instrument was its record of the great Indian earthquake of June 12. A short note descriptive of this record was read before the Royal Society of Edinburgh by Mr. Heath, and an enlarged reproduction of the photograph will be found in vol. xxi. p. 481, of the *Proceedings* of the Society. Since the above date several well-marked disturbances have been recorded. Two of these are clearly identified with the earthquakes of

August 5 in Japan, and Sept. 17 in Turkestan. Another is, with some probability, identified with the earthquake in Peru on Sept. 20.

The Dunecht Meridian Circle was finally placed in position late in 1896. A rigorous examination of the division errors for each degree of the circle was commenced by Dr. Halm, employing Nyrén's method, in 1897 October, and finished before the end of the year. Dr. Halm has also undertaken a determination of the flexure of the instrument. A series of observations of fundamental stars has been commenced for the purpose of testing the accuracy of the determination of the division errors, and of the provisional value of the flexure.

The electric control for the driving clock of the 15-inch refractor was completed by Mr. Ramsay in January, and has since worked satisfactorily. This telescope was employed during the first three months of the year by Dr. Halm in completion of the spectroscopic observations of the planets *Venus*, *Mars*, and *Jupiter*, commenced in the preceding year. In April Dr. Halm began a new series of observations of the chief lines in the brighter planetary nebulæ.

A grant placed at the disposal of the Astronomer Royal for Scotland by the Joint Permanent Eclipse Committee, enabled him to arrange an expedition to India to observe the total solar eclipse of 1898 January 22. Preparations for this purpose were commenced in September, all the apparatus to be taken to India being mounted for adjustment, and the necessary computations made by Mr. Ramsay. When the whole equipment was complete and packed, the boxes were shipped for India in the middle of November. Professor Copeland and Engineer Macpherson started from Edinburgh early in December.

Only one of the *Edinburgh Circulars* was issued during the year—No. 52—containing an ephemeris of *Comet Perrine* (1896 November 2) by Dr. Otto Knopf, of Jena.

The laying-out of the grounds about the Observatory, a much needed improvement, was begun by H.M. Office of Works in November, and is still proceeding.

An extension of the electric light installation to the outlying Observatory buildings was carried out by H.M. Office of Works in July.

Royal Observatory, Cape of Good Hope.

The Lords Commissioners of the Admiralty and of H.M. Treasury have favourably considered the representations made by H.M. Astronomer both in regard to an increase of staff and the provision of a new reversible transit circle, with an observatory suitable for fundamental work.

Mr. W. H. Finlay, M.A., has been promoted to the rank of chief assistant, Mr. J. Lunt, B.Sc., has been appointed assis-

tant, chiefly for work connected with the McClean telescope. Messrs. Pett and Cox remain as second-class assistants (old establishment). Messrs. Power and Woods become established computers, higher grade; Messrs. Pead, Woodgate, Goodman and Cochrane are added to the staff as established computers. Mr. R. T. A. Innes has been appointed on the permanent staff for secretarial duties.

The details of plans for the new transit circle have been fully discussed and finally settled; a contract for the completion of the instrument by the end of 1898 has been arranged with Messrs. Troughton & Simms. Plans of the new observatory for this instrument have been made at the Cape, and tenders for its construction have been called for by the Admiralty.

The MS. of definitely reduced Cape observations of comets 1879–94 has been forwarded for printing. This will form Part 1, vol. i. of the Annals of the Cape Observatory—instead of a history and description of the observatory, for which this place was originally reserved.

The page-size of vol. i. (demy quarto) having been found too small for many purposes, and especially for an illustrated description of the observatory, a royal quarto size was adopted for vol. ii. and all succeeding volumes of this publication. A new title page to Part 2 of vol. ii. (which was printed before the change of size was decided upon) will be issued, to convert this part into Part 5 of vol. i.

Volume ii. will contain, besides Part 1 already issued:

Part 2. A complete catalogue of known Southern double stars.

Part 3. Observations for change of latitude with the Zenith telescope.

Part 4. Results of general observations with the Zenith telescope.

This volume will probably be completed during 1898.

A history and description of the observatory is relegated to a future volume so as to include an account of the McClean observatory and of the new transit circle.

Volume iii. of the Cape Annals (being part 1 of the Cape Photographic Durchmusterung) was completed last year.

Volume iv., being Part 2 of the same work, and containing the places and magnitudes of 158,000 stars, derived by Professor J. C. Kapteyn from the Cape photographs between the limits of declination $-38°$ and $-52°$ (both inclusive) has been passed through press.

Volume v., Part 3 of the same work:—the MS. has been forwarded for printing as far as Decl^{n} $-60°$, and Professor Kapteyn reports that the remainder of the MS., carrying the work to the South Pole, is nearly ready, and will be complete long before the work as far as $-60°$ has been passed through press.

Volume vi. Part 1 of "A Determination of the Solar Parallax and Mass of the Moon from Heliometer observations of the

Minor Planets *Iris*, *Victoria*, and *Sappho*." The final sheets were passed for press on March 18, but the volumes were not delivered at Greenwich for distribution till November 16.

Volume vii. Part 2 of the above, was completed in 1896, and it will be distributed with its sister volume.

The meridian observations, made under the direction of Sir Thomas Maclear 1860–65 and recently reduced, have been printed, and should be ready for distribution. The reductions of the remaining part of this work, 1866–70, are well advanced.

The greater part of the Cape 10-year Catalogue of 3007 stars has been passed through press. The preparation of the introduction has been somewhat delayed by an elaborate comparison which has been made with other catalogues.

A separately bound appendix to the meridian observations 1890–91 containing the new Cape star-reduction tables by Mr. Finlay is ready for distribution, as also are the meridian observations 1892–95.

Copies of the independent day numbers, 1897, for use with the star-reduction tables were distributed from the Cape in May last. The corresponding day numbers for 1898 have been passed through press and advance copies sent to the chief observatories. The MSS. of the day numbers for 1899 and 1900 have been forwarded for printing.

The work of the present transit circle has been confined to observations of the standard stars required for the reduction of the international "Catalogue plates." The whole of the standard stars for the zone $-40°$ to $-43°$ (both included) have been observed at least 5 times each. This list provided a minimum of 10 well distributed stars for each plate.

The observations made with the transit circle during the year have been :—

Transits	9371
Determinations of Z. D.	8743
" Collimation	97
" Level	331
" Azimuth	267
" Run	325
" Nadir	312
" Flexure	43
Obs. of Meridian Marks in Azimuth ...	162
" " in Z. D.	37

Of these observations :—

The computations of Mean R.A. are complete to 1897, December 1.

The computations of Mean N.P.D. are complete to 1897, October 27.

Ledger prepared to 1897, April 7. Apparent N.P.D. to 1897, December 31. Star corrections to 1897, December 31.

The selection of the Standard Stars for the remainder of the Cape Catalogue plates is nearly complete. The working list for 1898 is prepared from 0^h to 18^h. By diminishing the number of observations of each star to three or four, and observing when necessary in double watches, it is proposed to complete the meridian observations of the Standard Stars for the remainder of the Cape Zones, viz. from 44° to 51° (both inclusive) by the end of 1899, so that the observers may be at liberty to take up fundamental work with the new transit circle in 1900. The whole will constitute a catalogue of over 9000 Standard stars between Dec. —40° and —52°.

Observations of 152 separate phenomena of occultations were obtained as follows :—

	D.D.	R.D.	D.B.	R.B.	Total.
Predicted by the N. A. office	26	13	2*	...	41
Daylight Occultations of *Antares*	...	1	...	...	1
Miscellaneous occultations	107	2	1	...	110
	*η Piscium and Antares		Total	...	152

Of these phenomena, three were observed by three observers, and twenty-one by two observers each.

Comet I. 1897 (*Perrine*) has been observed on eight nights by Mr. Finlay, with the 7-inch equatorial. The results have not yet been published.

Mr. Innes has been chiefly occupied in the revision of four lists of stars communicated by Professor Kapteyn in 1896 December.

I. 90 Stars contained in catalogues of precision and missing in the C.P.D. between Dec. −38° and −53°.

II. 247 Stars of mag. 9·0 or brighter, contained in Thome's Durchmusterung, and missing in the C.P.D. between Dec. −22° and −34°.

III. 19 Stars, mag 9·2 or brighter, contained in the C.P.D., and missing in Thome's Durchmusterung, Dec. −22° to −34°.

IV. 7 Stars suspected of variability.

All these stars have been under revision, many of them a great number of times. In no case has any error in the C.P.D. been found. The most interesting result has been the discovery, (*Ast. Nach.* 3464) that the 8th mag. star, Z.C. V^h. 243 (1875·0) $5^h\ 6^m\ 40^s$ − 44° 58′ has the largest proper motion of any yet known, being nearly 9″ of arc on the great circle per annum.

The following stars, in addition to the lists published *Ast. Nach.* 3426 and 3441, have been proved variable :—Equinox 1875.

h m s 9 3 48·6	° ′ −28 29·7	Th. 8·8: C.P.D. 10·2, found certainly variable. 9·0 to 9·8, period 250 to 300 days.
6 49 33·2	−24 0·6	C.P.D. 8·6: visually variable 8 7 to 9·3, no period recognisable.
19 56 25	−55 54·2	C.P.D. 9·0 to below 10·4, has been noted 11·5 till below visibility.

About 20 suspected variables are still under observation, and a number of errors in other catalogues have been traced.

Partly in connection with this work, and partly as the result of special search, Mr. Innes has found 128 new double stars, excluding those which had been previously discovered, and were by oversight entered in discovery-lists, and also pairs found previously, and almost simultaneously by Professor See in Mexico.

Of these new pairs 61 are under 1″
" " " 36 " between 1″ and 2″
" " " 24 " " 2″ and 5″
" " " 7 " " 5″ and 10″

Stars of the last class consist of a bright star with very faint companion.

Those found previous to 1897 March 24, are published *Ast. Nach.* 3419.

Those found previous to 1897 June 30, are published *Ast. Nach.* 3438.

Those found previous to 1897 Oct. 13, are published *Ast. Nach.* 3462.

In course of this work, the need of a complete catalogue of all known double stars south of the Equator has been constantly felt, and since his arrival at the Cape, Mr. Innes has devoted his spare hours to its preparation. The work is now complete to the end of 1897, and it is proposed to print it in Volume ii. of the Annals.

On nights of bad definition, Mr. Innes has searched for Comets without direct success, but has noted several uncatalogued nebulæ, of which particulars will be communicated to the Society.

Two young observers, Messrs. Goodman and Löwniger have been trained in the use of the Heliometer, and plans have been made for systematic heliometer observation of all the major exterior planets near each opposition. The comparison stars necessary for this purpose have been selected for all the oppositions till the year 1900 inclusive. A printed list of these stars will be shortly circulated, and the co-operation of Astronomers provided with good meridian instruments is earnestly invited for their observation.

To increase the accuracy of the results of meridian observations, steps have been taken to connect by Heliometer triangula-

tion the whole of the stars which will be employed at the opposition of each planet. It frequently happens that a number of different oppositions may be observed, in which all the comparison stars employed may be connected together in the same system of triangulation. Thus for example, we have:

Triangulation I., connecting together the thirty-six stars which are required for Heliometer observations of the oppositions of

Uranus in May 1898, 1899 and 1900.
Saturn in May 1898.
Jupiter in May 1900.

Triangulation II., which connects together nineteen stars required for Heliometer observations of *Neptune* in 1897, 1898, 1899 and 1900.

A triangulation of twenty-one stars in the neighbourhood of the South Pole has been arranged, the object being to combine Heliometer observations of their mutual distances with all existing meridian observations of the brighter stars situated within about 2° of the pole and to form definitive plans of them for the Equinox 1900.

The following observations have been made with the Heliometer since work was systematically commenced in July.

Of the eighty-three pairs of stars measurable in Triangulation I., every pair has been observed at least once either in position-angle or distance; there have in all been made in this triangulation—

103 observations of distance.
63 „ „ position-angle.

Of 122 measurable distances in the South Pole Triangulation, forty-one pairs have been observed twice, and ten pairs once. As this work can be continued at any season of the year, it is reserved to fill the observer's time when other work is not pressing.

The above numbers do not include the observations of the standard stars in each triangulation. The standard stars are observed at the beginning and end of each night's work, or if more than three or four pairs are observed, the standard stars are also measured in the middle of the work.

Nine complete sets of observations were obtained of the planet Neptune at last opposition. In each set the angular distance of the planet from four symmetrically situated comparison stars was symmetrically measured. Each set of observations thus consisted of thirty-two pointings. Very extensive co-operation on the part of meridian observers will be necessary to secure an accuracy in the places of the comparison stars corresponding in any degree to the precision with which the position of the planet relative to these stars is thus determined.

A few Heliometer observations connected with stellar

parallax, double star, &c., have been made by Dr. Gill and Mr. Finlay. The reductions of the 7-inch Heliometer observations for parallax of the principal southern stars have now been taken up, and the following series have been definitively discussed and prepared for press :—

Star.	Parallax.	Prob. Error of π.	Prob. Error of the Single Obs.	Mag. of the Comp. Stars.	Observer.
	"	"	"		
β Orionis	0·000	±0·010	±0·060	8·4 and 8·5	Gill
β Centauri	+0·046	±0·017	±0·084	8·0 „ 8·0	„
Sirius	+0·370	±0·0097	±0·070	8·7 „ 8·7	„
Canopus	0·000	±0·011	±0·073	8·5 „ 8·5	„
α Gruis	+0·015	±0·007	±0·042	8·0 „ 8·0	„
Antares	+0·021	±0·012	±0·084	6·5 „ 8·0	Finlay
Fomalhaut	+0·130	±0·014	±0·075	8·5 „ 8·5	Gill

In the column "Prob. error of the single observation," the probable error given is that of the *difference* of the two opposite distances measured. The probable error of the *locus* of the principal star projected on the great circle joining the two comparison stars is therefore half of the quantities given above.

The reductions of the following series are far advanced :—Observer Gill, α *Crucis*, β *Crucis*, β *Hydri*, α *Eridani*, α *Virginis*. Observer Finlay, ε *Orionis*, *Canopus* (2nd series), and β *Crucis* (2nd series). Of these only β *Hydri* appears to have considerable parallax. The complete memoir containing these discussions will probably be printed in Volume viii. of the *Cape Annals* in the course of the year 1898.

Regular observations with the zenith telescope have not yet been resumed, as the origin of some anomalous results in former series have not yet been completely traced. A preliminary note, prepared by Mr. Finlay, on the Change of Latitude, and on the Constant of Aberration, from observations by Gill and Finlay, 1892–94, has been communicated to the Society. The complete work is in preparation for press, and will appear in Volume ii. of the Annals. In the years 1886–91 436 pairs of stars were observed with the zenith telescope, as a rule on six nights each. These observations have been reduced during the year, and the results will also appear in Volume ii. of the Annals. As the stars which compose these pairs are all contained and well observed in the *Cape General Catalogue* for 1890, and as they are all symmetrically distributed in R. A. and Dec., and the northern components of the pairs have all been observed by Dr. Romberg, and will appear in the next *Pulkowa Transit Circle Catalogue*, these observations become of considerable interest in connection with the determination of fundamental declinations.

To H.M. Astronomer and every member of the staff, one of the most interesting events of the year was the visit paid by

Mr. McClean to the Observatory, where he lived and worked from the middle of May to the end of August. In September and October he was joined by Mrs. McClean with other members of his family, and resided in another suburb of Cape Town, but Mr. McClean visited the Observatory nearly every day and every clear night. The normal work of the astro-photographic telescope was suspended on April 20 in order to attach the mounting of Mr. McClean's 20° objective prism of 12 inches aperture to the instrument, and to make preparatory arrangements for balancing the telescope. Thus, within a few days of his arrival the prism which Mr. McClean had brought with him was mounted and counterpoised, and he commenced the completion of his spectrographic survey of the heavens to stars of $3\frac{1}{2}$ magnitude by making pictures of such spectra as he could not obtain in the latitude of Tunbridge Wells. Mr. McClean sailed from the Cape in the end of October, having successfully accomplished his principal object. His visit is a memorable one, not only from the scientific results which he secured, but from his constant kindness to all, and the many benefits he conferred on the Observatory during his visit. There is but one regret to record in connection with this visit, viz. that the telescope which the Observatory owes to his liberality did not arrive from Dublin as Sir Howard Grubb led us to expect that it would, and Mr. McClean was thus deprived of the pleasure of witnessing its erection. It is the hope of every member of the staff that Mr. McClean will soon revisit the Observatory and see the telescope we owe to him in full working order. The McClean Observatory itself is completed as far as possible, but until the heavy parts of the stand arrive, the final partition-wall cannot be erected, nor the entrance hall be finished. The rising floor, designed by Mr. McClean and Mr. Osbert Chadwick, and constructed by the Glenfield Company, of Kilmarnock, has been erected by Cape workmen under the supervision of H.M. Astronomer; it works to perfection. The lower portion of the iron pier of the telescope has arrived, and is erected and oriented. It is understood that Sir Howard Grubb has the rest of the instrument now nearly ready for shipment.

Previous to April 20 the following work was accomplished with the Astrographic telescope :—

	No. of Plates.	No. of Exposures.	Duration of Exposure.
Chart Plates	46	138	30^m each
Do. interrupted	6	8	5^m to 30^m
Plates exposed on stars suspected of variability in connection with revision of the C.P.D.	13	15	6^m
	3	3	10^m to 30^m

After October 27 the instrument was readjusted, object-glass and clock cleaned, and sundry repairs and alterations carried

out, and the following plates connected with adjustments were taken :—

Trails for focus	11
Adjustments	11

After which the following exposures were made :—

Charts (even zones)	2	2	40^m and 45^m
" (odd zones)	26	78	30^m each
Interrupted	3	7	10^m to 30^m
Catalogue plates (repetitions)	24	72	6^m 3^m 20^s
Rejected	1	3	6^m 3^m 20^s
Standard Area	1	3	6^m 3^m 20^s
Plates exposed on suspected variables, &c.	14	14	10^m to 30^m

Very little has been done in measuring the plates pending the new experimental arrangements which have been made for this work. A new instrument for measuring photographic plates, devised by H.M. Astronomer, has just been received from Messrs. Repsold. The new apparatus and methods promise to give even greater rapidity of work than Professor Turner's method, without sacrifice of the accuracy obtained with the older form of the filar micrometer. A description of the instrument, with examples of its work, will be communicated to the Society.

A geodetic survey of Rhodesia has been sanctioned by the Government of the British South Africa Company and placed under the direction of H.M. Astronomer. The selection and beaconing of the points of the principal chain of triangulation is nearly completed.

The time-signal service has been regularly maintained. The meteorological observations made during 1897 have been communicated to the Cape Meteorological Commission.

Cambridge Observatory.

The Cambridge contribution to the *Catalog der Astronomische Gesellschaft* has been published and distributed in the course of the year. It contains the mean places, reduced to epoch 1875·0, of 14,464 stars, each of which has been observed, on an average, about four times. The extreme limits in declination are 24° 15′ and 30° 57′ N., but only few are beyond 24° 45′ and 30° 15′.

The following extract from the Introduction will show the reliance that may be placed in the results.

To obtain the probable errors in right ascension and declination, "it was intended at first to examine all the stars of which five observations and upwards had been taken; but as 916

observations of 141 stars brought the work up only to $0^h\ 50^m$ right ascension, it was thought better to limit the examination afterwards to seven observations and upwards. Two stars only were omitted which gave decided evidence of proper motion; and one observation was rejected which differed in right ascension considerably from the others, while the star was marked in the memorandum-books *very faint*. The final result, from 7461 observations of 945 stars, gives for the probable error of one observation

$$\text{in R.A. } 0^s\cdot06608 \pm 0^s\cdot00040$$
$$\text{in Decl. } 0''\cdot5079 \pm 0''\cdot0031$$

"About 9000 places in this catalogue have been compared with the older catalogues, more especially Weisse's Catalogue of Bessel's Zone Stars, the British Association Catalogue of Lalande's Stars, Rümker's and Struve's Catalogues, the more exact places of stars in the Durchmusterung given in vol. vi. of the *Bonn Observations*, occasionally with Piazzi and Bradley, and in a few cases with the earlier Greenwich Catalogues."

"The results of these comparisons are tabulated in a condensed form, and will be given with a larger edition of the catalogue. This edition," now ready for the press, "will contain the results of the individual observations, with dates and number of wires, and the precessions in right ascension and declination, tables being given from which the secular variations of the precessions may be easily deduced. A very large number of the discordances appear to be due to systematic errors in the zones of Lalande and Bessel. In one instance the places of several stars which were found in two of Bessel's Zones—309 and 323—differ in Weisse's Catalogue, systematically, about $1^s\cdot4$ in right ascension."

A list has been made out of all the stars in the catalogue which have only been observed once, and a few that gave decided indications of proper motion, or about which a question had arisen, comprising 1420 stars. More than half of these have been re-observed with the meridian circle in the course of the year and reduced to epoch, adopting, as in the catalogue, the Berlin places of the standard stars.

The usual precautions have been taken to obtain a sufficient number of observations for clock and instrumental corrections.

Thus the meridian circle has been constantly, and we trust usefully, employed, as far as weather would permit; and the requisite calculations are nearly up to date.

The Northumberland equatorial has been chiefly used in the endeavour to awaken an interest among the undergraduates for astronomical work, by admitting them freely, on Saturday evenings especially, to the examination of the heavenly bodies.

The Newall Telescope, Cambridge Observatory.

The Newall telescope was used for observation on eighty-two nights in the course of the year 1897, the weather having been more unfavourable for observations than in any other year since the instrument was set up at Cambridge.

The work of the year has been almost entirely connected with the determination of velocity in the line of sight, and with the study of special stellar spectra.

The results of the previous year had been found to differ more or less systematically from Vogel's results for many of the brighter stars. The long troublesome search for the cause of the discrepancy—referred to in last year's report—ended in January in the discovery of the fact that the compression of a spring connected with the prisms used for getting the comparison spectra produced a minute deflection of the collimator every time the prisms were used. This defect was easily and immediately remedied, and the work has been carried on without difficulty—except for the unfavourable weather during the year.

A short note was communicated to the Society (*Monthly Notices*, Vol. lvii. pp. 557–577) giving some account of the general method adopted in the work, and pointing out that the chief difficulty in accurate determinations of velocity lies in the identification of a definite line in the middle of a group of lines. A few examples of results are given in the paper, and the velocities determined at Cambridge are shown to be in good agreement with those determined by Vogel, Keeler and Belopolsky.

Dunsink Observatory.

For the first half of the year 1897 the meridian circle and chronograph were used for observing the stars mentioned in the report for last year.

During the year there have been in all 4400 observations made with these instruments. This number includes 106 observations of collimation, 137 of level error, 64 of the nadir point, and 16 of the error of runs of the microscopes. For determining the error of azimuth 74 transits of polar stars have been observed, for the error of the Dent sidereal clock 354 transits of standard stars, and for the equator point of the circle 273 zenith distances of these stars have been observed.

The observations of the working-list stars amount in both R.A. and declination to 1688.

Upon Dr. Rambaut's appointment as Radcliffe Observer at Oxford, systematic observations with the meridian circle (except for determining time) were discontinued, and the interval between July 17, the last day of observation, and the end of the year has been devoted to bringing up arrears of reduction

and preparing for the press all the observations made with the meridian circle during the last two years which are not included in the seventh part of the Dunsink publications. In this work, as well as in the observations upon which it is based, Mr. Martin has displayed the greatest vigour, and has succeeded during the five months from July to December in reducing to catalogue form 4022 observations of 1101 stars.

This work will shortly be published as Part VIII. of *The Astronomical Observations and Researches made at Dunsink.* The probable errors computed in the usual way show that this work is of a high order of accuracy. The probable error

in R.A. as computed from 3473 observations is $\pm 0^{s}.033$

and

in Decl. as computed from 3397 observations is $\pm 0''.48$

The Roberts equatorial has been used as heretofore for stellar photography, principally in photographing star groups and clusters. The plates containing photographs of *Comet b* 1896 have been completely measured and reduced, and the results published in the *Monthly Notices* for June 1897.

Preparations were made for photographing the *Leonids* of November 13 and 14, using a 5-inch photographic doublet of about 16 inches focal length, with which it was hoped some trials might have been obtained, but unfortunately every night from the 12th to the 16th proved cloudy.

The post of Royal Astronomer of Ireland and Professor of Astronomy in the University of Dublin, which became vacant by the appointment of Dr. Rambaut to be Radcliffe Observer at Oxford, has been filled up by the appointment of Mr. Charles Jasper Joly, Fellow of Trinity College, Dublin, who assumed his duties as Director of the Observatory on December 21.

Durham University Observatory.

The routine work during the past year has been confined to meteorological observations, which have been taken regularly. The fund which has been collected for the purchase of an almucantar to supplant the existing transit circle is now well forward, and the construction of the instrument will be proceeded with as soon as possible.

Glasgow University Observatory.

In the first half of the year the work with the Transit Circle was preliminary in character. It included the determination of the division errors for every degree, those of every fifth degree having been derived in the previous year. The measurements were made by means of a twin-microscope which has two object-

glasses and micrometers and one sliding eye-piece. At the beginning of August the observations of the rectangular co-ordinates of the principal pole-stars and of three stars which are nearest the pole were begun.

The greater part of the time was, however, devoted to the spectroscope which is connected with the twenty-inch Breadalbane reflector. The 60° prism, which measures 6½ inches on the side and 3¾ inches high, was returned in February after having been reannealed, and the definition is now as good as can be expected.

Besides the ordinary adjustments of the spectroscope, lengthy experiments were made on the flexure of the apparatus and on methods of getting rid of it. Four object-glasses achromatised for different portions of the spectrum had been supplied for the collimator, in which the ratio of aperture to focal length is one in nine, and the focal curves were worked out from photographed spectra. An object-glass designed for visual purposes gave the best results although the plate has to be inclined 18° between *F* and *G* and 30° in the ultra violet. It was found that the inclining of the photographic plate has no appreciable effect on the definition, indeed the lines of the iron spectrum appear without halo and of such definition that 0·3 Angström units are sharply separated near *H*. During the experiments it became apparent that great changes of temperature in the dome destroy the definition, and that after a sunny day it is impossible to obtain satisfactory results. This is a serious disadvantage attached to the employment of a very large prism.

Since October photographs of the brighter stars were taken with the object of ascertaining the proper length of exposure. Although every opportunity was utilised there were only a few nights available. The weather was exceptionally bad in November and December, and when clear the atmosphere was either hazy or so damp that the mirror and prism became covered with dew. On two occasions *Arcturus* and *Vega* were photographed in daylight, the atmospheric spectrum serving as reference. In other cases iron and calcium spectra were used for comparison. The plateholder is so constructed that its position can be adjusted on an artificial spectral line during the exposure on a star and thus any length of exposure can be given.

Some experiments on the sensitiveness of photographic plates proved that this can be somowhat increased if a thin film of vaseline is spread over it. This action is perhaps due to fluorescence.

It was found necessary, owing to the damp weather, to re-silver the twenty-inch mirror twice during the last three months.

All the reductions have been kept up to date and a series of tables for the reduction of observations, made with the spectroscope, transit circle, and refractor, have been computed.

The time-service and the extensive meteorological work have been carried on as in former years.

Liverpool Observatory.

The instrumental equipment of the Liverpool Observatory remains the same as last year, with the exception that a seismometer has been mounted in the basement, with the co-operation of the Earthquake Committee of the British Association. This instrument, which is a form of bifilar pendulum, has been mounted to record displacements in the plane of the prime vertical. The adjustments were complete in September last, and the record has been regularly maintained since, but no certain indications of movement have yet been registered.

The arrangements for testing the accuracy of chronometers, &c., remain as in former years. About 200 marine chronometers have been under examination at the observatory during the year. The firing of the time gun has been regular and accurate.

The meteorological observations and automatic registrations have been maintained as usual. The Dine anemometer mentioned in the last report works satisfactorily, and an extended series of comparisons between the records of the Robinson and Dine anemometers has been made, and is being still further continued.

The meteorological observations made in the past year have been printed and circulated by order of the Mersey Docks and Harbour Board.

The occultation of the *Pleiades* was fairly well observed on July 23 and again on January 3 of this year with the 8-inch equatorial. The same instrument has been used regularly for the observation of those comets that were sufficiently bright to be observed, and the results will be communicated to the Society as in former years. The circumpolar stars, whose places were published by Professor Auwers in *Astronomische Nachrichten* No. 3440, have been regularly observed in right ascension as frequently as possible with the transit instrument, and the results have been forwarded to him.

Three courses of lectures have been given in connection with the classes at University College, Liverpool, and these have all been well attended.

Radcliffe Observatory, Oxford.

During the year the Observatory has suffered the loss by death of its eminent and distinguished Director, Mr. E. J. Stone, M.A. (Cantab. et Oxon.), F.R.S., who for the last nineteen years has conducted its affairs with such success.

Dr. Rambaut, late Royal Astronomer of Ireland, was appointed to succeed him as Radcliffe Observer, and assumed the direction of the Observatory on October 20. In the interval which elapsed between the death of Mr. Stone in May and his

successor's assuming the duties of Radcliffe Observer in October, the affairs of the Observatory were conducted by the First Assistant, Mr. W. Wickham, on the same lines as in recent years, and the routine work has thus been carried on with but little interruption, notwithstanding the changes which have occurred.

With the transit circle the observation of a zone of stars between the equator and 5° north declination, commenced during the previous year, has been continued; also the places of many zodiacal stars, not included in the Radcliffe Catalogue for 1890, and which are required for use in the *Nautical Almanac*, have been secured. The Sun was observed on the meridian 36 times and the Moon 45 times; but since September, owing to pressure of other work upon the staff, the Moon has not been put on the observing list after Full.

The Barclay Equatorial has been used in the following observations: Comet *Perrine* (1896 December 8), observed on two nights; Comet *Perrine* (1897 October 26), on one night. Various other attempts to secure observations of comets were ineffectual owing to the faintness of the object when seen, or failure to pick it up at all, as in the case of Comet *Brooks*.

The magnitude of *Nova Aurigæ*, which had apparently remained fairly constant at 9½ for the previous four years, was noted on 1897 March 10 to have fallen as low as 11½, and observations made on twenty nights since then have failed to detect any further marked change up to December 31. During the interval May to November the star was not conveniently placed for observation. The occultation of the *Pleiades* by the Moon on July 23 was observed here, and the results have been communicated to the Society. Among the miscellaneous work with this instrument may be mentioned: Observations of the magnitude of B.D. $+51^\circ\cdot244$, which was noted as 9·5 by Argelander (in reality there are two stars of nearly equal magnitude, about 11 mag., and separated from each other by 46″); also observations of other stars of suspected variability; positions of faint comparison stars for comets; occultation of *Ceres* by the Moon; examination of nebulæ and red stars.

The heliometer has been used as an equatorial telescope for observing occultations, and, the moving parts having been thoroughly cleaned, a number of observations have been taken as a test of the working of the semi-lenses and of the instrument generally, with a view to judging of its practical value as a measuring instrument during the coming year.

The *Leonid* meteors of 1897 November 13 were observed, and the results are printed in the *Monthly Notices* for December.

The meteorological observations and automatic registrations have been regularly maintained as usual, and the results have been communicated to public institutions as well as to private inquirers. The four platinum thermometers, acquired at the end of the year 1896, have been supplemented by two others; one has been placed 10 feet below the surface of the soil, whilst the

other has been used in the observing room for comparison with mercurial thermometers and for other purposes. These thermometers and the associated resistance apparatus are exceedingly sensitive and delicate, and certain initial difficulties have been encountered in getting them into working order. The solution of these difficulties and the determination of the fundamental points of the scale for each thermometer have necessarily consumed a large amount of time, but a good deal of light has been thrown on some interesting points connected with them, and it is anticipated that they will prove very useful for determining the seasonal changes of temperature at various depths in the ground.

University Observatory, Oxford.

The measurement and reduction of the Catalogue plates has proceeded throughout the year quite satisfactorily, by the help of the grant of 150*l.* annually from the Government Grant. This is the second year out of the five during which it is proposed to ask for this grant. Four or five computers (of ages ranging from 15 to 18) have been employed on the work at the Observatory, and Mr. Moore, of the Leeds Astronomical Society, has also done a considerable share of measuring.

As stated in the last report, each plate is measured twice over, in reversed positions. A comparison of the figures set down on the two occasions shows that the "errors of bisection" thus eliminated are very small, and might have been neglected, *i.e.* measurements made in one position only are practically good enough; but the measures in the reversed position are most valuable as an independent check on the measures in the first, and will be continued throughout the work. (See *Monthly Notices*, vol. lvii. p. 621, &c.)

During the year 500 plates have been measured in one position or the other, with an average of 290 stars on each, involving the record of 145,000 stellar positions. Since each image is measured twice, and since each star occurs on at least two plates, this corresponds to the cataloguing of about 35,000 separate stars. These large numbers indicate the power of the photographic method.

As regards the reductions, places of the stars observed on the meridian at Cambridge and Berlin have been converted into "standard coordinates" for the whole of zones +25°, +27°, and +28° (18,000 stars), zone +26° having been done last year. These coordinates have been compared with the measures, equations formed and solved, and formulæ of correction thus obtained for 170 plates.

In the last report a hope was expressed that the measurement and reduction of zones +26° and +27° (360 plates) might be completed by the end of 1897. This has not been found practicable, the above-mentioned 170 plates being all that are

completed, and some of these being in other zones; but about 100 other plates are well advanced towards the final stage. One reason for the falling short in the number of plates expected is that too low an estimate had been made of the number of stars per plate. This was expected to be 200, but the average for the year is 290. Now, this is a serious increase, and if maintained would clearly render it difficult to get the work done in the proposed time. On examination, the increase was found to be in great measure due to the enormous number of stars on plates exposed to the Milky Way. The greater photographic brightness of these has been already remarked by Kapteyn and Gill; a practical result of it is that while the number of stars shown on poorish plates in regions remote from the Milky Way is 2 or 3 times that of Argelander's charts, this ratio may rise to 10, 15, or even 20 for good plates in or near the Milky Way. For instance, on three consecutive plates in $+26°$, R.A. $17^h\ 36^m$, $17^h\ 44^m$, and $17^h\ 52^m$, there were measured 1166, 1379, 1111 stars respectively; Argelander only giving 62, 83, and 98, and the Cambridge Catalogue 44, 39, and 54. Now, there does not seem sufficient reason for measuring all these stars and protracting the work accordingly. A determined attempt is being made to complete within the proposed time an adequate survey of the region allotted to this Observatory, for reasons which need not be elaborated here; but, as the same difficulty will arise at other observatories, it may be well to state here the procedure which has been adopted to obviate it.

(1) A plate is accepted if there are on it three times as many stars as given by Argelander for the same region; or if there are at least 300 stars on it.

(2) In future the third exposure of 20 seconds will be extended to 1 minute.

(3) Before measuring a plate the number of stars showing all three exposures is counted. If there are 300 of these, or "three times Argelander" (which *may* happen even with a 20-second exposure), *these only* are to be measured. If there are not, the number showing two exposures will probably not be excessive.

The following table shows the rate at which the measures are being made. In two periods of ten weeks each, ending on the dates given, there were measured :—

Date.	Star-places.	Plates.	Hours Occupied.	Number per Hour.
1897 March 27	22361	90	573	39
1897 September 25	32989	68	547	60

As regards the accuracy of the measures, it is shown in the paper already quoted (*Monthly Notices*, vol. lvii. p. 621) that the probable error of a resulting coordinate is sensibly less than $\pm 0''\cdot 20$, the limit assigned by the Conference. An independent

check on the accuracy is afforded by the Cambridge meridian observations. The discordances which appear in the course of the work are nearly always traceable to errors of computation, sometimes clearly to large proper motion, and very seldom* indeed to any error in the recorded measure. All such cases have been satisfactorily explained. One case was outstanding for some time, there being two meridian observations at Cambridge of a star which did not appear on our plates, but it was ultimately identified as the well-known variable *T Andromedæ*!

It is a pleasure for the director to record his appreciation of the admirable way in which Mr. F. A. Bellamy has organised and superintended this important but most laborious piece of work throughout the year.

Temple Observatory, Rugby.

The work of this observatory has been continued as usual. It has been largely of an educational character, and it is hoped that the value of the Observatory in this respect is increasing. During the later portions of the evenings the measurement of double stars has been continued, and it is thought that with the limited means at disposal no better work can be carried on.

Stonyhurst College Observatory.

The meteorological and magnetical continuous records have been carried on as usual, and reports sent to the Meteorological Office and Registrar-General.

The grating of the solar spectrograph was cleaned on Oct. 14, and it is now in a better condition than when first used by the present director in 1890. Fifty-four trials on the H–K region of integrated solar light have been made since the date of cleaning, and these appear to show that only the best photographs can be accepted in evidence against the existence of the double reversals of calcium light. Owing mostly to the unfavourable state of the sky, only half the number of plates exposed since October 14 developed into good photographs. On all of these one at least of the pair of bright lines is plainly seen, generally both; and always the more refrangible of the two is the stronger. On the same day a good photograph has shown the double reversals, while an inferior one, taken nearly at the same time, has failed. For this reason nearly all the previous plates, exposed to the duller grating surface, have been rejected, as not affording reliable evidence against the existence of the lines.

One hundred and seventy-four drawings of Sun-spots and faculæ have been made to the usual size, and a series of enlarged drawings of spots near the limb was commenced in the middle

* Mr. Bellamy remembers only two such cases occurring among 5000 stars compared.

of September with the hope of obtaining evidence of greater value about the level of the umbra.

Two hundred and forty photographs of stellar spectra have been obtained. The greater number of these are repetitions suggested by a preliminary examination of the plates already in hand.

Twenty-one photographs of the spectrum of *o Ceti* have been obtained during its period of maximum brightness, and a complete map and table of wave-lengths have been prepared for presentation to the Society. The spectra of other stars of the same class are under examination at present, with the object of forming a comparison series.

Dr. Common's Observatory.

During the past year the 5-foot has been mounted as a Cassegrain. The mirror having been refigured very slowly, some trial photographs give very good images of the four stars in the trapezium of *Orion*. Some 12-inch cœlostats have been made and some 30-inch mirrors with holes in centre, and work on plane mirrors has been carried on very successfully.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

The work of this Observatory during the year 1897 differed in no special respect from that of recent years. The planets *Jupiter*, *Mars*, and *Venus* received most attention, but measures of a few binary stars were also made. The planetary observations have already appeared in the *Monthly Notices* of the Society. The usual meteorological observations were made daily at 9 A.M. and 3 P.M., and monthly reports sent to the Registrar-General; the usual rainfall reports, both summary and detailed, have been sent to Mr. Symons and others.

The new 9-inch triple object-glass by Messrs. T. Cooke & Sons has continued to give perfect satisfaction.

Wolsingham Observatory (Rev. T. E. Espin's).

During the past year sweeping for stars with remarkable spectra has been continued, and 235 stars of types II., III., or IV. have been observed. A catalogue of all the stars observed with the spectroscope since 1886 has been commenced. This has been divided into three parts: the first, containing 848 stars observed 1886–92, the second, containing 1380 stars observed 1892–94, have been completed, while the third, containing the observations 1895–97 has been completed as far as xvi. hour, and contains 858 stars. Observations of various suspected

variable stars have been continued during the year, and the following have been added to the list for confirmation :—

	°	h m	° ′	Variation.	Type.
Es 968*	B.D. + 62·161	0 45·3 (1900)	62 23	8·4 to 9·5	III.
Es 972	+ 45·624	2 27·0	45 13	8 „ 9	III.
Es 867*	+ 26·3486	19 9·1	26 36	8·6 „ 9·8	III.
Es-Birm 649*	+ 41·3632	20 6·3	41 12	8·9 „ 9·5	IV.
Es 911*	Anonymous	20 30·0	54 37	9·3 „ 15	III.
Es 1232	+ 67·1283	21 0·4	67 46	6·8 „ 8	I.

The stars marked * have been so far observed as to leave no real doubt as to their variation. The last star is suspected to have a double spectrum of dark and bright lines, and is the centre of N.G.C. 7023. Some plates have been taken with the 8-inch photo-telescope of several suspected variable stars.

Sir William Huggins' Observatory, Upper Tulse Hill.

The series of photographs of stellar spectra, which include the ultra-violet region of the spectrum as far as reaches us through the Earth's atmosphere mentioned in the last report, has been continued, so far as weather has permitted, during the past year. These photographs are taken with Iceland spar and quartz spectroscopes attached to a Cassegrain reflector, with metallic specula, of 18 inches aperture.

Advantage has been taken of a recent modification of the reflecting slit employed by Sir William Huggins in 1875, which was described in *Astronomy and Astro-physics*, 1893 August, p. 618, to take separately the spectra of closely associated stars.

Early in the past year an automatic mechanical arrangement was devised for giving the necessary breadth to stellar spectra on the photographic plate, which has been found to answer admirably in several respects—namely, by diminishing considerably the irksomeness of constant personal attention; by the saving of time of exposure, since every moment tells upon the plate; and by increased uniformity of photographic action throughout the breadth of the spectrum. This arrangement consists of a toothed wheel, through which the clock motion passes on its way to the driving-screw, which is furnished on one half of its circumference with one tooth more, and on the other half with one tooth fewer than the number of teeth required to transmit the clock-motion without alteration.

With the assistance of these improved arrangements, photographs have been taken separately of the spectra of the two brightest of the small stars forming the trapezium in the nebula of *Orion*. These spectra, confirming others taken during the last two years, show that bright radiations are associated with the

corresponding dark lines, and in most cases not symmetrically, but more or less to one side. A comparison of the photographs taken from 1894 leaves little doubt that the relative positions of the dark and of the reversed bands are subject to change, suggesting the class of phenomena present in *β Lyræ*, and in *Nova Aurigæ* soon after its first appearance. This investigation is still in progress. The dark lines of the hydrogen series can be traced as far as Hπ. The calcium line K is very thin, and is near a bright radiation which may or may not be associated with it.

The spectra of the contrasted coloured components of double stars have been separately photographed, among others those of the components of *β Cygni*, *α Herculis*, *Cor Caroli*, and *γ Leonis*. The study of these spectra is of great interest in connection with the probable evolution of binary stars, in which case they should be of the same age, and composed of the same substances, though not necessarily in the same proportions. In the case of blue and yellow components, the small blue star shows a type of spectrum more or less after the order of the white stars, which are regarded as evolutionally earlier than the solar type to which the brighter yellow star usually approximates. It may be, however, that the less bright blue star may be of greater mass, and so behind the other in evolutional progress.

It may be stated that in the spectrum of *α Lyræ* sixteen dark lines can be counted beyond H, so bringing the hydrogen series up to H ϕ. The spectrum itself extends on the plate as far as λ 3000.

In the laboratory, experiments on the spectrum of calcium have led to the important fact that density is the determining factor in the modifications of its spectrum as seen in the celestial bodies. The hitherto perplexing behaviour of the H and K lines, often appearing alone, as in the prominences, is shown to be what takes place normally when the density of the calcium vapour is of extreme tenuity, as it must be in the solar prominences. Under these conditions, photographic spectra have been obtained, consisting solely of H and K, the latter line being the stronger of the two, as is the case in prominence-spectra photographed by Hale and by Deslandres. These results furnish us with an experimental criterion by which the relative densities of stellar atmospheres, when suitable lines of calcium are present, may be ascertained.

Other lines of research, both in the observatory and in the laboratory, are also in progress.

Rousdon Observatory, Lyme Regis (Mr. C. E. Peek's).

The building and equipment of the Observatory has been maintained in its usual order. The weather has on the whole been unfavourable, but observations have been made on 156

nights. This is somewhat below the average. The 6·4-inch equatorial has been kept at the regular observation of long-period variable stars on the same lines as during the previous eleven years, and 463 determinations of magnitude have been made. Twenty maxima and 23 minima have been observed. Twenty-five long-period variables are under regular observation; these being mostly circumpolar, the light variations are continuously recorded.

Variable Star Notes No. 2 has been recently published and distributed. This contains the observations of *T Ursæ Majoris* and *S Cephei* for the ten years 1887 to 1896. The results are given concisely in tabular form, accompanied by diagrams of the light curves.

Transits of stars have been taken as often as required for the rating of the sidereal clock.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The work done at this Observatory during the past year will be estimated by the following list of selected photographs which have been taken with the 20-inch reflector, and is given in continuation of similar lists which have been published in the *Monthly Notices*, vol. lvii. pp. 261, 262 and in the volumes for the previous years. The photographs are available for reference, as also are those taken in former years.

A photograph, 15 degrees in diameter, of the sky surrounding each of the objects in the list has been taken with the 5-inch Cooke lens simultaneously with the reflector photograph, and it is hardly necessary to repeat that upon hundreds of the special photographs which have been taken with the 20-inch reflector during the past twelve years there is much matter that is new to astronomers that ought to be preserved in a permanent form for correlation with other photographs which will be taken in future years.

This important subject is now receiving close attention, and it is the more pressing for the reason that the very sensitive photo-films (which are used and are essential to success in recording the very faint nebular and other faint objects in the sky) will not survive the lapse of many years without serious deterioration. The films will cease to show the faint nebulous structures originally visible upon them, and they will gradually become darker in colour, until ultimately the faint stellar images and nebulosity will cease to be visible.

List of the Principal Photographs taken in 1897.

	R.A.		Decl.		Expos.
	h	m	°	′	m
Neb. H IV. 42 Piscium	1	43	+ 5	23	90
Neb. H I. 105 Ceti	1	48	−14	16	90
Neb. H IV. 23 Ceti	2	22	− 1	38	90
Neb. H I. 64 Ceti	2	41	− 8	1	90
Nebulæ in the Pleiades	3	40	+23	46	$4^h, 8^h, 9^h 2^m$, and 10^h
Neb. H I. 155 Eridani	3	41	− 4	18	90
Neb. N.G.C. 1499 Persei	3	54	+36	8	90
Neb. H I. 258 Persei	3	55	+51	1	90
Neb. H II. 524 Eridani	4	31	− 3	22	58
Neb. H V. 49 Persei	4	32	+50	14	90
Neb. H I. 122 Eridani	4	36	− 3	3	59
Neb. H V. 33 Orionis	5	20	− 2	37	90
Neb. H V. 34 Orionis	5	31	− 1	16	2^h
Cl. H VI. 5 Orionis	6	8	+12	50	60
Cl. H VI. 28 Monocerotis	6	33	+10	59	60
Cl. H VIII. 31 Monocerotis	6	42	− 3	3	60
Cl. H VI. 18 Monocerotis	6	51	− 7	3	60
Neb. H IV. 55 Lyncis	8	5	+46	18	90
Cl. M. 48 Hydræ	8	8	− 1	38	60
Neb. H I. 242 Ursæ Majoris	8	46	+51	43	90
Neb. H I. 132 Hydræ	9	16	−11	28	90
Cl. H VI. 4 Sextantis	9	50	+ 4	46	60
Neb. H I. 164 Leonis Minoris	10	30	+37	52	90
Neb. H IV. 60 Ursæ Majoris	10	32	+54	3	90
Neb. H V. 7 Leonis	10	38	+15	26	90 and $2^h 51^m$
Neb. H I. 94 Ursæ Majoris	11	35	+38	7	90
Neb. H I. 203 & II. 733 Ursæ Majoris	11	49	+44	43	81
Neb. H I. 174 Comæ	11	58	+32	29	90
Neb. H IV. 56 Ursæ Majoris	11	58	+44	57	90
Neb. H I. 225 Ursæ Majoris	12	1	+53	18	90
Neb. H V. 4 Virginis	12	3	+ 3	27	75
Neb. H V. 41 Canum Ven.	12	12	+38	23	90
Neb. H V. 5 Comæ	12	16	+18	58	90
Neb. H I. 30 Virginis	12	19	+ 7	54	90
Nebæ. M. 87, 89, 90 Virginis	12	28	+13	21	90
Neb. H I. 43 Virginis	12	34	−11	3	90

	R.A. h m	Decl. ° ′	Expos. m
Nebæ. ♅ I. 14, 15 Virginis	12 38	+ 0 20	90
Neb. ♅ I. 42 Virginis	13 4	− 7 16	90
Neb. ♅ I. 85 Comæ	13 6	+23 29	90
Cl. ♅ VI. 7 Comæ	13 11	+18 14	60
Neb. ♅ I. 98 Boötis	13 37	+36 11	90
Neb. ♅ V. 6 Boötis	13 41	+16 50	90
Neb. ♅ I. 6 Virginis	13 51	+ 5 47	90
"Leonid" meteor swarm ...	14 12	− 5 26	57
" " " ...	14 25	− 7 30	2h 45m
Neb. ♅ I. 126 Libræ	14 40	+ 2 25	90
Neb. ♅ I. 280 Ursæ Minoris ...	16 37	+78 25	79
Neb. ♅ IV. 50 Herculis ...	16 44	+47 44	60
Cl. M. 14 Ophiuchi	17 32	− 3 11	2h 18m
Neb. ♅ VI. 41 Draconis ...	17 33	+75 48	2h 49m
Neb. ♅ IV. 37 Draconis ...	17 59	+66 38	60
Neb. Σ 6 N. Taur. Poniat. ...	18 7	+ 6 49	60
Cl. M. 16 Clypei	18 13	−13 50	2h
Hind's var. neb. in Aquila ...	19 6	+ 0 52	2h 15m
Stars in Cygnus	19 45	+35 30	60
Neb. ♅ IV. 72 Cygni	20 8	+38 5	74 and 2h 51m
Neb. ♅ IV. 13 Cygni	20 12	+30 15	60
♅'s Nebulous Region No. 42 ...	20 43	− 1 53	90
" " " " 43 ...	20 53	+16 44	90
" " " " 45 ...	20 57	− 1 34	90
Neb. ♅ IV. 52 Cassiopeiæ ...	23 16	+60 37	60

Mr. Wilson's Observatory, Daramona, Streete, co. Westmeath.

During the early part of the year some stellar photographs were taken with the 24-inch reflector. The later part of the year has been cloudy and wet.

Early in the year a special form of Cinematograph was ordered for the 4-inch photo-heliograph, in order to try whether it would be possible to show visually the changes in the forms of Sun-spots. Unfortunately the instrument could not be got from the makers until the end of the year, when the Sun was too low to use it. Measures of the radiation of Sun-spots were continued when a spot of sufficient size was visible.

Hong Kong Observatory.

Hourly meteorological observations and continuous records, weather forecasts, storm-warnings, magnetic observations, and the public time-service have been continued as usual. During the summer and autumn the Director attended the British Association meeting in Toronto and the American Association meeting in Detroit, and visited a number of observatories and weather-bureaus in America, especially the Emerson McMillin Observatory, Columbus, Ohio, where he acquainted himself with the latest advances in spectroscopy under Professor H. C. Lord. During his absence Mr. Plummer continued the astronomical observations, and Mr. Figg took charge of the meteorological work. The number of observations of pairs of stars made by Talcott's method is as follows:—1896 October, 135; November, 165; December, 207; 1897 January, 101; February, 61; March, 7; April, 51; May, 134; June, 26; July, 144; August, 152; September, 165; October, 147; November, 230. The number of observations made is limited by atmospheric conditions, and shows the regular annual period which characterises the weather here. With reference to the time-service, the greatest interval of cloudy weather during which no observations were obtained was 16 days in 1897 January and February, after which the error amounted to $0^s.5$. The greatest period previously met with amounted to 23 days in 1887 January and February, after which the error amounted to $0^s.9$.

Melbourne Observatory.

Meridian Observations.—These were made with the 8-inch meridian circle, and are as follows, viz.:—

Observations in R.A. clock stars	687
„ „ R.A. list stars	999
„ „ R.A. azimuth stars	230
Total	1916
Observations in N.P.D. list stars	1003
„ „ N.P.D. azimuth stars	146
Total	1149
Observations for level	345
„ „ collimation	129
„ „ flexure	13
„ „ runs	45
„ „ nadir	102

Reductions.—The separate results and catalogue for 1896 have been completed, and the greater part of the stars observed in 1897 finally reduced. The list stars are, as in previous years, stars selected from the plates of the Astrographic Catalogue, to be used as zero stars in connection with and reduction of those plates.

Time Service.—The time-ball was dropped at the old lighthouse at Williamstown at 1 P.M. standard time on 304 days, and time signals were supplied every day to all telegraph stations in the colony, to the railways, public departments, and places in town. The time-ball failed to drop on three occasions owing to faults on the line.

Stellar Photography:—

Catalogue plates	...exposed	53	rejected	4
Chart plates (single exposure of one hour) ...	"	75	"	13
Plates for Oxford Type regions	"	9		
" " trails	"	22		
" " for adjustment of centre	"	11		
" on the region surrounding the South Pole	"	28		

Exposure for Catalogue plates, 5^m, $2\frac{1}{2}^m$, and 20^s.

" " Chart " 60^m.

The rejected plates were found faulty on account of imperfect setting, broken exposure, or insufficient sensitiveness. Ilford star plates have been used throughout. The Melbourne series of catalogue plates is now complete. The total number of chart plates passed as satisfactory is 172.

Magnetic Work.—The photographic registration of the three magnetic elements has been carried on throughout the year with very few accidental interruptions. Absolute measurements of horizontal force, declination, and dip, were made on 15 occasions.

Meteorological Service.—The number of rainfall stations has increased this year to 552. Two forecasts have been issued daily at 1 P.M. and 6 P.M. Rainfall statistics and meteorological records for all stations in the Colony for the year 1896 were reduced and published, and those for 1897 are being made ready for the press. This work has been generally carried on as in former years.

Rating of chronometers and testing of meteorological and nautical instruments have been continued as usual.

Special Cloud Observations.—These observations have been made throughout the year in connection with the scheme of the International Meteorological Committee. Some 12 observers terminated their work in June last, and 18 have continued it till the end of the year. Some 20,000 observations have been collected of cloud form, direction of motion, and apparent velocity, while the measurements of absolute height and velocity of clouds have been carried on at two stations (one of which is the

Melbourne Observatory), by simultaneous photographs taken with cameras permanently adjusted with their optical axes truly vertical, as mentioned in last year's report. This work has proved very interesting, and a large number of paired pictures have been obtained, several of which have already been measured and have given satisfactory results. The length of the present base is 6820 feet, which is only adapted for the higher clouds, and it is intended to continue the work a few months longer with a shorter base. A detailed description of the method employed in taking the pictures, making the adjustment, measuring and deducing results, will be given in the proper place.

General Remarks.—In October last, Mr. F. N. Ingamells, who had left the Observatory in April 1895 in consequence of a retrenchment scheme put forward by the Government at the time, was reinstated in the position of Clerical and Meteorological Assistant, and since then, by a re-arrangement of routine duties, the Astrographic Observer has been and will in future be enabled to devote the whole of his time to astrographic operations, and it is thus expected that the taking of the chart-plates will now be proceeded with at a more satisfactory rate. The Astrographic Observer had hitherto to discharge several daily duties which necessitated his attendance from 9 A.M. till 5 P.M., and could not therefore be expected to utilize more than 3 hours in the earlier part of the night—namely, before 11 P.M. It is for this reason that the photographic chart has progressed so slowly in the past years.

In every other respect, however, the conditions of the Observatory are the same as reported last year. Consequently it has not been found possible to make systematic observations with the Great Telescope and other equatorials; to publish astronomical results which have been ready for the press for some years; to reduce and prepare for publication the existing material in connection with the Great Telescope and terrestrial magnetism, nor to commence the measurement of the plates of the Astrographic Catalogue. Other important operations, among which is the determination of the division error of the transit circle, and the preparation of a general catalogue, including the meridian observations of the past 13 years, had also to be postponed. These matters were mentioned in the report to the Board of Visitors to the Observatory in August last, and the Government was urged by the Board to provide the necessary assistance to place the Institution in a more efficient condition.

The Director went to Sydney early in January to discuss with the Director of the Observatory of that place, Mr. H. C. Russell, the best means of measuring and reducing the Catalogue plates, and it was agreed and decided that all the plates of both Observatories are to be measured at Melbourne by a Bureau consisting of the Astrographic Observer at this Observatory, and four women, to be specially trained for this work. The expense is to

be shared by the two institutions, and the approval of the respective Governments is awaited, as well as the necessary funds to carry out these intentions. In regard to the meridian circle observations of 10 zero stars for each Catalogue plate, the Adelaide Observatory has continued to assist in these observations, and it is intended to ask the Perth Observatory, when ready, to join in similar work.

The complete Catalogue of such stars will include some 13,000 places or more, of which some 3300 only have been completely observed.

Natal Observatory.

The observations made at the Natal Observatory during the year 1897 have been confined to those necessary for carrying on the ordinary routine work.

The outbreak of rinderpest having cost the colony nearly three quarters of a million of money, the printing of the results of the astronomical work done at the Observatory has been postponed *sine die*. The manuscript of the memoir on the corrections required by the lunar tables to bring them into accord with observations found in the comparison with theory of the whole series of Greenwich observations between 1750 and the present time, is to be done up in brown paper, tied up with red tape, and carefully stowed away on a shelf for an indefinite period, as its length—some 250 pages—would possibly render it too long for the Memoirs of the Society.

The tables founded on the results obtained can be reduced into a form which could be printed without much expense as soon as the necessary time can be found for recasting them.

One of the more interesting facts established is that, owing to an important factor having been overlooked in determining the value of the equation of the centre from the discussion of the observations, all the values hitherto obtained for the eccentricity of the Moon's orbit are incorrect. That deduced by Airy from the discussion of the Greenwich observations for 1750–1851 must be changed from $22639''\cdot06$ to $22645''\cdot09$. This will necessitate changes in the whole series of numerical values given by Hansen, Delaunay, and others as the theoretical values of the principal inequalities in the motion of the Moon. Thus Delaunay's value for the evection is really $4589\cdot0$ instead of $4586\cdot4$. Hansen's value for the motion of the lunar perigee also requires material modification.

Perth Observatory, Western Australia.

The astronomical instruments have not yet been received from the makers; they are, however, now completed, and will shortly be erected. The Government of Western Australia sent the Government Astronomer to England in May last in order to

inspect these prior to shipping them, and he considers that they are in every way satisfactory. A short description is given in the report for last year. With the transit-circle the principal work will be the determination of the exact positions of the 480 stars in the southern heavens selected some years ago by Dr. Auwers. Some attention will also be paid to reflexion observations in view of the possibility of R – D discordances, as it is hoped that, owing to the peculiar construction of the transit room, irregularities of refraction inside the room will be avoided.

Sydney Observatory.

There has been no change in the staff, but Mr. Sellors was absent for four months making computations for another Government Department, in accordance with the rule of the Public Service Board under which a temporary pressure of work in one department may be met by *borrowing* an officer from another, and on this occasion the Observatory had to suffer.

Meridian observations in R.A., clock stars	445
„ „ „ R.A., zone stars	535
„ „ „ N.P.D., clock stars	445
„ „ „ N.P.D., zone stars	535
Determinations of level	392
„ „ collimation	298
„ „ nadir...	392
„ „ azimuth	94

Level and Nadir are observed every morning except Sunday to furnish data on the slow change in the foundations of the instrument.

Equatorial.—Only 50 evenings were available for double star measures. 28 other fine nights had to be devoted to visitors.

The number of Double stars measured	101
Settings for position angle	503
„ „ distance	529

Eighty-three of the double-stars measured are found in the Sydney lists of new pairs for 1882 and 1883.

Astrographic.—Plates taken for Catalogue	1
„ „ „ Chart	385
„ „ „ tests	13

Exposures of over 1 hour are no longer possible in Sydney, because all the city gas lights have been converted into incan

descent burners, and this light, reflected by dust and smoke, fogs the plates.

The effort to remove the Observatory this year has proved unsuccessful, but it is hoped that it may succeed later.

Meteorological.—Weather charts, with forecasts, have been issued every forenoon, Sundays excepted; and since the beginning of August a second chart and forecast has been issued at 9 P.M.; the public reognise this later information as a material improvement.

A system of publishing charts of the colony showing whenever rain falls, the amount, and locality, has been accepted by the public as a great convenience.

General.—One book and eight pamphlets have been published, and of these, in all 3332 copies have been distributed, and in addition 17,500 weather charts, and we have received from other Observatories 1039 books and pamphlets, which have been all duly acknowledged. The number of meteorological observing stations has increased to 1,565.

915 persons have visited the Observatory during the year.

Lovedale, South Africa (Mr. A. W. Roberts's Observatory).

No observations of variable stars were made here during 1897. A visit to England during the year was made the opportunity for the reduction of all the observations from 1891 to 1896. This reduction gave rise to several allied matters (the question of the amount and nature of the error arising from relative position of the stars in the field being one) which require further observation for their full elucidation. The publication of the final results may therefore be delayed for a time.

Mr. Tebbutt's Observatory, The Peninsula, Windsor, New South Wales.

The weather during the year 1897 was pretty favourable for astronomical undertakings. The following is a summary of the work done.

Meridian Department.—The work with the Cooke & Sons 3-inch transit instrument and John Poole 8-day sidereal chronometer comprises the following:—

Nights on which the local time was determined ...	168
Stars observed with a declination not exceeding 40° ...	921
Stars in high declination observed for azimuth ...	244
Separate determinations of level error	508
Separate determinations of collimation error	45
Separate determinations of azimuth error	182

The variations of level of the axis of the transit instrument have been great during the year, and frequent adjustments were necessary. The other errors were not so variable.

Extra-Meridian Department.—With the Grubb 8-inch equatorial refractor the following micrometer comparisons were obtained :—

Object.	Nights of Observation.	No. of Comparisons.
Hebe (6)	4	58
Parthenope (11)	13	125
Niobe (71)	7	122
Procne (194)	14	170
Uranus and 41 Libræ	8	213
Neptune and 114 Tauri	6	120
Comet 1897 I. (Perrine)	21	235

Planet *Niobe* was observed in high south declination, and the work on Comet Perrine was nearly all done in the morning sky. In addition to the above observations, 134 phases of lunar occultations of stars and numerous phenomena of *Jupiter's* satellites (February to July) were recorded, chiefly by means of the 8-inch equatorial. In a few cases the Cooke & Sons 4½-inch equatorial refractor was employed. Lastly, comparisons of the variable star *R Carinæ* were made on twenty-nine nights extending from January 4 to August 31.

The author of this report is indebted to Mr. Joseph Brooks, F.R.A.S., for his predictions of occultations of *Nautical Almanac* stars for the first eight months of the year; to Professor R. Luther, of Düsseldorf, for MS. ephemerides of small planets; to Mr. C. J. Merfield, F.R.A.S., for comparisons of the planet observations with the ephemerides; and to Professor H. Kreutz and Mr. C. D. Perrine for early ephemerides of Comet 1897 I., discovered by the latter.

The meteorological observations were made as usual, but at the close of the year this department, with the exception of observations of rainfall and of extreme monthly temperatures, was discontinued, after being maintained for a period of thirty-five years. Some portions of the observations will be continued by the Government at the Hawkesbury Agricultural College, about four miles west of the observatory.

NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS OF ASTRONOMY DURING THE PAST YEAR.

Discovery of Minor Planets in 1897.

Seven new planets were discovered during the past year as follows :—

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1897.	Discoverer.	Place of Discovery.
DH	426	...	Aug. 25	Charlois	Nice
DJ	427	...	27	"	"
DK	428	Monachia	Nov. 18	Villiger	Munich
DL	...	...	23	Charlois	Nice
DM	...	...	Dec. 18	"	"
DN	...	...	18	"	"
DO	...	...	18	"	"

The following planets discovered in December 1896 have received permanent numbers since the date of the last report ; DB 423, DC 425, DF 424. DD and DE do not receive permanent numbers, not having been sufficiently observed.

The planet provisionally named DG, discovered by Charlois on August 25, proves to be identical with (188) *Menippe*, which had been missing since 1878, the year of its discovery.

The following planets have been named : (348) *May*, (350) *Ornamenta*, (354) *Eleonora*, (416) *Vaticana*.

The following planets have been observed at one opposition only : 99, 132, 155, 156, 157, 193, 220, 285, 290, 293, 296, 307, 310, 314, 315, 316, 319, 320, 323, 327, 328, 330, 340, 341, 353, 355, 357, 359, 360, 361, 365, 368, 382, 383, 388, 392, 393, 394, 395, 397, 398, 400, 401, 403, and 404. All the other planets, from 1 to 405 inclusive, have been observed at two or more oppositions.

M. Simonin has investigated the orbit of (108) *Hecuba*, the theory of whose motion is interesting but difficult, on account of its period being so nearly half that of *Jupiter*. (*Annales de l'Observatoire de Nice*, t. vi.)

He finds that log a varies between the limits 0·5061 and 0·5104, n between 608″·7 and 618″·6, ϕ between 3° 30′ and 6° 0′. Although he has neglected powers of e beyond the second, yet he

has been able to represent all the observations during 25 years with no error exceeding 4′.

He points out that it is quite possible for a planet whose eccentricity is subject to large perturbations to remain permanently invisible when the eccentricity is a minimum, but to become visible at perihelion when it is a maximum.

Dr. Backlund contributes two papers on the terms of long period in the longitude of the same planet. (*Bulletin Astronomique*, 1897 September and 1898 January.) He points out two methods by which the coefficients in the expressions for these terms can be greatly reduced, and their convergence correspondingly improved.

A. C. D. C.

The Comets of 1897.

Omitting mention of elliptic comets of short period, whose return could be foretold, only one comet has been discovered during the year. We must go back a considerable time to find so barren a record.

Of the comets mentioned in the last report, but whose history was necessarily incomplete, one, that discovered by Mr. Perrine on December 8, was followed in large telescopes up to the beginning of March of this year. Whether the observations will prove sufficiently numerous and long in continuance to permit the orbit to be determined with the accuracy necessary to decide the question of connection with *Biela* is still doubtful. The other, that discovered by the same astronomer on November 2, was observed in the southern hemisphere till the following April; but though the comet came again above our horizon in the summer, it appears to have been too faint and too near the Sun to have been re-observed.

D'Arrest's Comet, for which M. Leveau provided an ephemeris, was discovered at the Lick Observatory by Mr. Perrine on June 28. He speaks of it as being visible in a 3¼-inch finder, but owing to its proximity to the Sun and the long twilights of that time of the year it does not appear to have been generally observed in Europe. The error of the ephemeris was about four minutes of time in right ascension and rather more than four minutes in declination, which could be approximately removed by reducing the mean anomaly twenty minutes. A sufficient number of observations have been made to secure improved elements.

On October 16, Mr. Perrine discovered a telescopic comet in *Camelopardalus*, moving rapidly towards the pole. Owing to the moderate brightness of the comet and its favourable position in the sky, it was very generally observed, and numerous measures have been collected. In ordinary telescopes the appearance of the comet was not very striking, but in the 36-inch of the Lick Observatory a well-defined nucleus was clearly seen, and at the time of discovery, when the comet was near to its maximum

brilliancy, a tail could be traced for some three or four minutes. A photograph taken by Professor Hussey showed a tail extending ten minutes from the nucleus with sufficient clearness to permit the measurement of the position angle. The comet faded more rapidly than the formula expressing the theoretical brilliancy intimated, and by the middle of November it had practically disappeared. The orbit is likely to prove parabolic.

Although Winnecke's Comet was first seen in the current year, it seems desirable to mention its discovery in this place. Again we are indebted to the careful scrutiny of Mr. Perrine for this fortunate recovery, who shortly before sunrise on January 2 picked it up, guided by the ephemeris of Dr. Hillebrand, by whom the calculations have been undertaken since the lamented death of Professor v. Haertdl, whose researches on the motion of this comet are well known. The ephemeris, rapidly prepared to prevent any delay in rediscovery, proved to be about two minutes of R.A. and nine minutes of δ in error. The theoretical brilliancy at the time of discovery was less than when found in 1892, suggesting an increase in intrinsic brightness, but the light of the morning sky will probably prove more effective in preventing observations than any actual faintness of the object.

Though two of the family of short-period comets have been recovered on their return to the Sun, two have unfortunately escaped. Spitaler's Comet of 1890, which probably passed its perihelion in March, has not been seen. The chances for seeing it, never very great, were best towards the end of 1896. The comet of Tempel-Swift has also been in perihelion early in June, but, notwithstanding the careful discussion of the perturbations by M. Bossert, of the Paris Observatory, and the construction of a more than adequate ephemeris to assist the recovery, it has not been seen, owing to the faintness due to its great distance from the Earth.

Among the more interesting contributions to cometary literature should be mentioned Dr. Holetschek's investigation of the magnitude and brilliancy of comets and comet tails, from the earlier times till 1760. The object which Dr. Holetschek proposed to himself in this inquiry was to arrange in order of magnitude those comets whose orbits have been computed, in much the same way that stars are classified by their brilliancy. In addition, an attempt has been made to derive the true length of the tail from the records of apparent length, and to examine to what extent the power of tail construction and the consequent apparent length may be concluded from a knowledge of the magnitude of the comet and its perihelion distance.

The data for determining the magnitude of a comet are necessarily vague and untrustworthy. Dr. Holetschek has had to rely on the record of a date when a comet first becomes visible, or when last seen, as furnishing a definite magnitude, but here such circumstances as twilight, moonlight, approach to horizon, &c., leave a doubt as great, perhaps, as when a comet is compared in

lustre with a planet or a first magnitude star. But from the experience gained in examining many original accounts of comet apparitions, Dr. Holetschek has learnt to translate the description with a fair amount of accuracy, and in many cases, when the comet's brilliancy has been reduced to that of unit of distance ($r=1$; $\Delta=1$) by the application of the ordinary formula $\frac{1}{r^2\Delta^2}$, the resulting magnitudes, derived from various sources, agree fairly satisfactorily. In long extended series of observations, the magnitudes for distance unity have a tendency to exhibit a regular progression, suggesting the inappropriateness of the general formula. Dr. Holetschek finds that Δ^2 is a justifiable factor, but the employment of the square of the radius vector is not so well founded. In modern instances, Encke's and Winnecke's comets both require a much higher exponent, but the value deduced, though it secures better arithmetical results, has no real physical signification.

Of the many historical accounts examined, some 70 lend themselves to a fairly satisfactory determination of magnitude at distance unity, and about 50 permit a numerical value to be assigned to the length of the tail. The magnitudes range from -1 (the great comet of 1744) to $9\frac{1}{2}$, but the greater number fall between the magnitudes $(4-6)$. The length of the comet's tail is necessarily an uncertain quantity, and it would not be safe to conclude more than that the tail is greater, the greater the magnitude, and the closer the approach to the Sun. When the magnitude of the comet for $r=1$, $\Delta=1$ is about the sixth, or less than the sixth, as a rule no tail is developed that can be seen with the naked eye, or only under the most advantageous circumstances, as when the comet comes near the Earth. With magnitude four, almost all comets when near perihelion have a tail visible without optical aid, but when the perihelion distance is large, as in the case of the comets of 1729 and 1747, the tail development is very slight.

Halley's Comet has been made the subject of a special examination, with the result that the magnitude at each return, when reduced to unit of distance, has remained fairly constant. For a thousand years, 837 to 1835, this magnitude has been between the third and fourth, while the length of the tail from 1456 to 1835 shows no great variation. Dr. Holetschek concludes from these figures that, notwithstanding the reasons which would suggest that at each return the comet must part with some of its materials, this loss is so small that it remains within the limits of uncertainty in deriving the magnitude of the comet.

W. E. P.

Progress of Meteoric Astronomy in 1897.

Photograph of the Spectrum of a Meteor.—Professor E. C. Pickering writes to *Ast. Nach.* 3461, that on 1897 June 18, when the 8-inch Bache telescope at Arequipa was directed towards the constellation *Telescopium* for the purpose of obtaining photographs of the spectra of stars, a bright meteor appeared in R.A. $18^h 19^m$, Decl. $-47° 10'$, and passed out of the field at R.A. $18^h 29^m$, Decl. $-50° 30'$. "The spectrum consists of six bright lines, whose intensity varies in different portions of the photograph, thereby showing that the light of the meteor changed as its image passed across the plate. The approximate wave-lengths of these lines are 3954, 4121, 4195, 4344, 4636, and 4857; and their intensities are estimated as 40, 100, 2, 13, 10, and 10 respectively. The first, second, fourth, and sixth of these lines are probably identical with the hydrogen lines $H\epsilon$, $H\delta$, $H\gamma$, and $H\beta$, whose wave-lengths are 3970, 4101, 4341, and 4862. The fifth line is probably identical with the band at wave-length 4633 present in spectra of stars of the fifth type, and forming the distinctive feature of the third class of these stars. The third line, which is barely visible, is perhaps identical with the band at wave-length 4200 contained in these stars."

An Enormous Block of Meteoric Iron.—Eighty years ago, when Sir John Ross discovered the Eskimos of the Cape York region, he found that the metallic knife blades, harpoon heads, and other instruments in use amongst them were formed of meteoric iron, said to have been derived from iron mountains in Melville Bay. Lieutenant Peary, travelling in this region in 1894, found one huge block and two smaller masses of meteoric iron, weighing respectively 200,000 lbs. (90 tons), 6000 lbs., and 1000 lbs., which the Eskimos had utilised for many years in making cutlery. In 1895 Lieutenant Peary brought the two minor ones back to America, and in the summer of 1897 he transported the large mass in the steamer *Hope* safely to New York. It measures 12 ft. by 8 ft. by 6 ft., and a sample of this enormous block, in the possession of its finder, looks like highly polished steel, and the beautiful Widmanstätten figures, forming the usual feature of meteoric irons, are finely marked upon it. An analysis has proved it to consist of 92 per cent. of iron and 8 per cent. nickel.

Perturbations of Meteoric Streams.—Professor Theodor Bredikhine, in the *Bulletin* of the St. Petersburg Academy, vol. v., November 5, gives the results, quoted in *Nature*, November 25, of his investigation as to what members of the solar system are responsible for disturbances in those meteoric systems encountered by the Earth in her annual orbit. He finds the Sun's effect is predominant in the great majority of cases, and especially so when the perihelion distance is small. In several instances,

however, there is a near approach to one or other of the major planets. Professor Bredikhine's previous inquiries as to the nature and motion of the tails of comets have indicated that the force of projection at the period of outburst is sufficient to change the paths of numbers of the constituent atoms from parabolic to elliptic orbits of short period. He adopts the view that meteoric systems generally are composed of the fragments of comets which, in traversing interplanetary space, lost a portion of their material by disturbing influences exerted by members of the solar system. The larger proportion of the meteoric streams examined by Professor Bredikhine have resulted from large disturbances at the nucleus caused by the Sun, and amongst these are the *Leonids*, *Quadrantids*, *Geminids*, and *Aquarids*. The *Orionids* owe their presence to the perturbations set up by *Jupiter*, while the *Lyrids* are due to *Saturn*.

Height of a Meteor found by Photography.—At the Lick Observatory, on 1896 November 13, $13^h\ 30^m$ to $17^h\ 8^m$ P.S.T., a meteor trail was photographed simultaneously on plates exposed in two cameras 1384 feet apart. Two different lenses were, however, employed, and the inaccurate focus of one of them, combined with the short base line, made it impossible to get very precise results as to the real path. Messrs. Schaeberle and Colton therefore determined to compute the height of the middle point of the path. The parallax was found to be $9'\cdot06$, and the distance above the surface of the Earth 99 miles.

January Meteors.—Mr. H. Corder, at Bridgwater, watched the sky on the night of January 1, and in about 6 hours of clear sky saw 109 *Quadrantids* and 21 other meteors. Mr. T. W. Backhouse, at Sunderland, saw 97 meteors on January 1, and of these about 86 were *Quadrantids*.

August Meteors.—Near the time of maximum moonlight was too strong for the shower to present any brilliant features. Professor A. S. Herschel, at Slough, made an extensive series of observations from July 20 to August 9, and during watches, amounting in the aggregate to 33½ hours, observed 280 meteors, of which 114 belonged to the great *Perseid* stream. As early as July 22 the shower formed a distinctly recognisable display from the point $23°+49°$, and on later nights took up positions to the E.N.E., in conformity with the usual displacement it exhibits.

In *Ast. Nach.* 3463 appears a summary of 78 radiants of the *Perseids* derived from a number of miscellaneous observations during the last five years. The comparison of these results exhibits the shifting of the centre very well, though there are irregularities obviously occasioned by the errors of observation.

November Meteors (Leonids).—M. Lucien Libert, at Le Havre, France, watched the sky on November 13 from 12^h to 18^h, and registered 51 meteors, including about 21 *Leonids*. The writer reprojected these observations, and found the radiant diffuse to the extent of 8°, with a centre at R.A. 150° Decl. +24°. Mr. W. E. Besley, of Westminster, maintained a look-out after midnight

on November 13 for $5^h 20^m$, and saw 27 meteors, of which 20 appear to have been *Leonids* from a radiant at R.A. 149° Decl. +23°. Professor E. C. Pickering, at Harvard, on November 13, reports that his observers saw only 90 meteors during the night, butthat these were nearly all *Leonids*.

On November 14 clouds appear to have veiled the sky nearly everywhere, and few accounts have come to hand. Professor Lewis Swift, writing from Lowe Observatory, Echo Mountain, Cal., says: "The *Leonids* made their appearance on the morning of November 15, as predicted, 97 having been seen by one person."

Mr. Robert Service, an amateur observer of Dumfries, writes that on November 14 the weather cleared up shortly after midnight, and the sky was free from clouds until daylight. Between $12^h 30^m$ and $16^h 15^m$ he saw 33 meteors (17 *Leonids*), and then went indoors, though the *Leonids* were increasing, more than half the whole number seen during the night being observed from $15^h 42^m$ to $16^h 9^m$. He was afterwards informed by two persons that, when proceeding to their work at about 5 A.M., November 15, their attention was attracted by numbers of shooting stars.

The shower of *Leonids* was fairly active on the morning of the 16th, for Herr Nyland, of Utrecht, observed more than 40 meteors, chiefly *Leonids*; and of these 10 were brilliant, several of them being comparable with *Venus*.

November Meteors (Andromedids).—Mr. P. M. Ryves, of Stone, Staffs., watched the sky on November 27, between $7^h 40^m$ and $9^h 44^m$, and counted 20 meteors, of which apparently 6 or 7 were *Andromedids*. The radiant point was near γ *Andromedæ*, but was not well defined.

Fireballs.—A considerable number of large meteors appeared during the past year, but very few of them were observed accurately at two or more stations. On April 30 at $9^h 37^m$ a fireball estimated $5 \times$ ♀ was seen by the writer at Bristol. The observed part of its path was from R.A. 166° Decl. +51° to R.A. 154½° Decl. +31°. It was seen at Stroud, Lyme Regis, and several other places, where its sudden and astonishing brilliancy startled the observers. At Lyme Regis it was estimated as half the diameter of the Moon. It descended from a height of 59 miles above Cheltenham to 18 miles above Banwell, Somerset, and traversed a real path of 70 miles at a velocity of 23 miles per second. Its Earth point was 4 miles N.W. of Taunton, and from this place it must have appeared as a brilliant stationary object in its radiant point at 291° + 59°.

On July 30 at $8^h 47^m$, in strong twilight a magnificent meteor was seen at Bridgwater, Southampton, Tunbridge Wells, Upton near Slough, Henley-on-Thames, Collumpton (Devon), Lyme Regis, and other places. It fell from a height of 54 miles over Poole, Hants, to 23 miles over the English Channel, after a flight of about 50 miles, and velocity of 13 miles per second. The observations are not quite accordant, and the radiant point is

not indicated with certainty; but it was near *β Ursæ Majoris*, and at about R.A. 155° Decl. +59°.

On August 2 13^h $57\frac{1}{2}^m$ a fireball 3 × ♀ was observed by Professor A. S. Herschel, at Slough, and Mr. H. Corder, at Bridgwater. It fell from a height of 81 miles over a point 10 miles E. of Tavistock, Devon, to 47 miles over Watchet, Somerset, after a visible course of 59 miles. It was directed from a radiant point on the equator at R.A. 312° Decl. ±0° in *Aquarius*.

On August 8 9^h 15^m a fireball excelling ♀ was seen by Professor Herschel at Slough, and by Mr. N. Lattey at Cardiff. The meteor appears to have been a *Perseid*, but the heights are unusual—viz. from 133 to 115 miles over Hampshire and the English Channel. The real path was about 63 miles; velocity about 42 miles per second.

On August 9 14^h 18^m another brilliant fireball 3 × ♀ was seen by Professor Herschel, and the same object appears to have been recorded by Mr. W. E. Besley at Exeter, but there is a doubt as to the magnitude, though the path conforms well. Again the resulting heights are excessive, for the meteor descended from 137 to 75 miles along a course extending over 75 miles.

These are not the only instances where the computed heights of doubly observed meteors at the August epoch were found to be over 100 miles. Yet it is very unusual to meet with a single case where even the elevation at commencement exceeds that distance. In the following table particulars are given as to the abnormal figures recently found :—

Date.	G.M.T.	Mags.	Height at Beginning.	Height at Ending.	Length.	Radiant R.A. Decl.
1897	h m					° °
Aug. 2	11 5½	2	112	90	40	40 + 55
2	11 24	5–4	139	124	28	73 + 66
8	9 15	> ♀	133	115	63	52 + 47
9	13 27	3–1	140	77	81	46 + 56
9	13 52	3	131	89	56	58 + 60
9	14 18	3 × ♀	137	75	75	44 + 45

The mean heights of these six objects are :—

At beginning = 132 miles. End = 95 miles.

Yet the mean values from six other meteors observed at the same period are only :—

At beginning = 63 miles. End = 49 miles.

In the autumn many fireballs were observed, but rarely with sufficient fulness or accuracy to enable their real paths to be determined. The dates of their appearance were October 19, 22; November 15, 19, 28, 29; December 3, 9, 12. The meteors of

December 9 and 12 were splendid objects, and attracted widespread notice. The former of these was a *Geminid* with radiant at about R.A. 113° Decl. +32°, and it fell from a height of 76 to 21 miles over Suffolk and Herts. The latter was a ζ *Taurid* from a radiant at R.A. 80° Decl. +23°, and it fell from 112 to 19 miles over the North Sea and Yorkshire.

W. F. D.

Sun-Spots and Faculæ During 1897.

The year 1897 opened with a slight increase of solar activity, as compared with the last quarter of 1896, and a magnificent spot group was seen crossing the Sun's disc from January 3 to 15. The group occasionally exceeded in area 2500 millionths of the visible hemisphere, and the principal spot approached 2000 millionths. No other group approached this one in magnitude, but the nearest were those seen early in February, May, August, and in the middle of December. Of all these groups the last was the only one north of the equator, so that judging from the larger groups above, the predominance clearly remains, as in 1896, with the southern hemisphere.

More remarkable than the spot groups of the year was the minimum that occurred in the last half of May and the first half of June. For a whole week, May 13–19, the Sun was free from spots, it was again free on June 7, 8, 10, 11, 12, 17, 19; while the mean daily spotted area for the six weeks beginning on May 11, was under 200 millionths.

The results for the end of the year are at present far from complete. On three other days at least, besides the fourteen above mentioned, the Sun was free from spots on March 21, April 23, 24; the Sun was free from faculæ on March 14, May 21, June 1, July 5, August 22, and September 6.

The mean spotted area for 1897 is as nearly as possible the same as that for 1896, the difference probably not exceeding 10 millionths of the visible hemisphere in the daily average.

P. H. C.

Poincaré's Mécanique Céleste.

New and important fields of research have been opened up to dynamical astronomers during the last twenty years. The impetus was originally given by Dr. Hill's papers on the Lunar Theory. Since then, Continental mathematicians have applied to the Problem of Three Bodies the varied resources of modern analysis. M. Poincaré, himself the most distinguished of living workers in this field, has collected the results of recent research in the three volumes of his *Méthodes nouvelles de la Mécanique*

céleste—a work of which we are glad to notice the approaching completion.

The first volume appeared in 1892. After two preliminary chapters—one on the general differential equations of dynamics, and one on integration by infinite series—the author commences in the third chapter the study of periodic solutions. Among the solutions of the general Problem of Three Bodies, there are some in which the relative movement repeats itself at regular intervals of time. A class of these "periodic solutions," as they are called, was discovered by Dr. Hill in his "Researches in the Lunar Theory," published in the first volume of the *Aemrican Journal of Mathematics*. Much of the theory in its present form is due to M. Poincaré himself. It was developed in a memoir on the Problem of Three Bodies, which gained the King of Sweden's prize in 1889, and it is the main theme of the present volume.

The problem attacked may be thus stated: In the Problem of Three Bodies, let two of the bodies have their masses zero. Then a class of periodic solutions of the system is known: namely, the motions in which these bodies describe circular orbits about the third body. Is there a corresponding class of periodic solutions when the two masses are small, but no longer zero? Existence theorems are given for such motions, and periodic solutions are arranged in three classes. It is shown that in the second and third of these classes the arbitrary constants of the motion must be such that no secular terms occur.

Much of the remainder of the volume is occupied with the theory of motions which differ only slightly from periodic solutions. Periodic solutions may at first seem to be of no practical interest. It is clearly unlikely that the initial circumstances of the motion will be such as to give rise to an exactly periodic motion. But it may very well happen that they differ only slightly from such values; the periodic solution can then be treated as a first approximation, or "intermediary orbit," just as Kepler's ellipse is in the older theories, and we can regard the actual motion as a disturbed form of it. Dr. Hill has developed the Lunar Theory in this way. M. Poincaré arrives at a general theory of "asymptotic solutions" and their "characteristic exponents." If the characteristic exponents are purely imaginary, the periodic solution is a stable form of motion. The case of the problem of three bodies is discussed at some length, and it is shown that the periodic solutions then have two, but not more than two, of their characteristic exponents zero.

An important chapter is devoted to the integrals of the equations of motion. Herr Bruns has proved (*Acta Mathematica*, xi.) that the Problem of Three Bodies, and, more generally, of n bodies, admits of no algebraic integral other than those already known. M. Poincaré now further develops this theorem by proving that for small values of one of the masses there is no uniform transcendental integral. Dr. Hill, however, considers the proof of this open to criticism.

The sixth chapter deals with the development of the disturb-

ing function, particularly in respect of the long-period inequalities. In seeking to complete his theorem on the non-existence of uniform integrals, the author has discovered an extension of Darboux's work on terms of high order in expansions.

The second volume, published in 1893, treats of the methods of Gyldén, Newcomb, Lindstedt, and Bohlin.

In the ordinary developments of the Planetary Theory the coordinates of the planets are expressed in terms of the time, as infinite series; by taking a sufficient number of terms of the series, it is theoretically possible to calculate the place of the planet with any desired accuracy. But these series have one great defect—they contain terms which increase indefinitely with the time. The efforts of mathematicians have lately been successful in obtaining series free from these "secular terms," as they are called. The developments thus obtained, however, are not convergent in the ordinary sense of the word; having in this respect some analogies with the well-known "semi-convergent" expansions for Bessel Functions. This, as M. Poincaré remarks, does not affect their use for purposes of calculation, but renders them useless for researches into the stability of the system.

Some of the reasoning on the convergency of the developments has, however, been criticised by Dr. Hill; there is room for further research in this connection.

Although the results obtained in the second volume are largely due to other workers, M. Poincaré has introduced considerable modifications in his account of their theories.

The third volume, of which the first part has lately appeared, includes the rest of the work originally given in the memoir "Sur le Problème des trois Corps," already mentioned. The theory of Integral Invariants, which was first developed there, is of importance in questions relating to stability. We can regard a system of ordinary differential equations as defining the motion of a point in space of n dimensions. If now we consider a group of points P, which occupy a ν-dimensional region ζ_0 at the beginning of the motion, they will at any time t occupy a region ζ. A ν-ple integral taken over ζ is called an "integral invariant" if it is independent of t. Thus, in the motion of an incompressible fluid, the volume of fluid contained in any given region is an integral invariant.

The importance of Integral Invariants arises from the following property. Suppose that the volume is an integral invariant, and that the representative point P always remains at a finite distance from its initial position. Then if we take any region of space, however small, there are always an infinite number of trajectories of P which traverse it infinitely often. This theory is applied to extend the discoveries on stability already made by Hill and Bohlin.

This work will be a noble monument of the dynamical astronomers of this generation, and its completion will be awaited with interest. E. T. W.

Professor G. H. Darwin's Researches on Periodic Orbits.

The problem of three bodies in its utmost generality is one far beyond the capacity of analysis in its present state to solve, and all that can be done is to consider a simple case and then the approximations to such simple cases.

It was usual to take as the simple case the problem of two bodies, and as the approximation, the case where the influence of one attracting body predominates largely over that of the other. The problem of two bodies leads to motion in a conic section, in general an ellipse; and in the cases of the problem of three bodies that occur in nature, the motion is for a time approximately motion in an ellipse. The drawback to this method of treatment is that the disturbing body, however small or distant, causes the apse and node of the ellipse to rotate, and the motion cannot for long approximate to motion in a fixed ellipse. It has been attempted to meet the difficulty by comparing the actual motion with motion in an ellipse whose apse and node revolve: but such a motion has no physical interpretation.

Since, therefore, part of the effect of the disturbing body is secular, and accumulates indefinitely, so that the approximation made in neglecting it loses its accuracy, it was found desirable to attack the problem from a different point of view, in which the influence of the disturbing body should be considered even in the simple case used as the starting point, and where the departures from the "intermediate" orbit should be wholly periodic and not secular.

In 1876 Dr. Hill pointed out that the proper intermediate orbit is that which results from neglecting the eccentricity and inclination, and consequently the evection, and also neglecting the eccentricity of the Sun's orbit. The variation and parallactic inequality are alone left, and the orbit, referred to a plane rotating uniformly with the Sun and upon which plane therefore the positions of the Earth and Sun are fixed points, is periodic, the period being a synodic month. The elliptic and inclinational inequalities, together with the evection, are free oscillations about this periodic orbit; the annual equation is a forced oscillation. As in other dynamical problems, the period of the forced oscillations is the period of the disturbance, an anomalistic year; the period of the two free oscillations result from the corresponding period equations, which Dr. Hill has obtained in the form of infinite determinants. Provided only that the periodic orbit is stable and the departure from it small, any required degree of accuracy may be obtained by expanding in powers and products of quantities representing the eccentricity of the Sun's orbit and the amplitudes of the two free oscillations.

The subject of periodic orbits thus opened by Dr. Hill has been pursued, by M. Poincaré and others, from the pure mathematical point of view. M. Poincaré has discussed general questions, such as the cases in which the existence of periodic orbits

may be inferred, their method of appearance and disappearance, as the circumstances are varied, and general laws concerning the periods of oscillations about them.

Professor Darwin has approached the subject from the numerical point of view. His object has been to draw as many orbits as possible, and to trace the changes of form corresponding to changes in the relative energy. He has been the first to extend numerical researches into those regions where the influence of one body no longer predominates over the influence of the other.

To magnify the disturbances, from the scale on which they occur in nature, Professor Darwin has assumed that the smaller attracting body, which he calls Jove, has a mass equal to one-tenth of the mass of the Sun. The relative orbit of Jove and the Sun is circular, the mass of the third body is negligible, so that referred to moving axes both Jove and the Sun can be represented in the diagrams as fixed points.

Taking some definite value for the constant of relative energy, Professor Darwin traces out, by mechanical quadrature, a number of orbits starting at right angles from the line of syzygies. The calculations are continued until the line of syzygies is again reached: if two orbits return to the line of syzygies at an obtuse and acute angle respectively, by interpolation an intermediate orbit can be obtained returning at right angles; the continuation of such an orbit is the reflection of the part already obtained in the line of syzygies; it is therefore re-entrant and periodic. In this way a large number of periodic orbits have been obtained, several for each different value of the constant of energy. A comparison of the results shows that the orbits fall into families, each family taking account of the modification of a different orbit, as the constant of energy varies.

Professor Darwin has also considered the question of stability. His methods are analogous to Dr. Hill's. When a series is required, it is obtained, when possible, by the method of special values. The method fails in the case of orbits of fantastical shape, but these may be, with confidence, classed as unstable.

Considerable information is obtained by considering the form of the curve of no velocity. For cases such as occur in nature, the form of this curve shows that the third body must remain a satellite, an inferior planet or superior planet, without changing its rôle. Professor Darwin has considered cases where the third body may pass from Jove to the Sun. Some of his orbits are cusped, the cusp lying on the curve of no velocity; later members of the same family are looped. In this case the manner of introduction of the loop is easy to follow out. Other orbits, however, pass from simple ovals into figures of eight; the manner of transition is at present obscure.

In his present paper Professor Darwin has only covered a small fraction of the ground that he has opened up. Now that the methods have been carefully devised, it should be com-

paratively easy for others to follow up Professor Darwin's work, and it is to be hoped that before long information on the subject will be extended.

P. H. C.

Dr. Gill's Determination of the Solar Parallax.

Volumes vi. and vii. of the *Annals of the Cape Observatory*, which have been recently published, are devoted to a determination of the Solar Parallax from heliometer observations of the minor planets, *Victoria*, *Iris* and *Sappho*. Previous experience had convinced Dr. Gill that the Solar Parallax might be determined in this way with great accuracy, and he secured the co-operation of the observatories at Yale, Leipzig, Göttingen, Bamberg, and Oxford (Radcliffe) in a carefully planned and extensive series of heliometric measures of the distances of these planets from neighbouring stars during their oppositions in the years 1888 and 1889. The principle of the method consists in the measurement of a planet's distance from two comparison stars situated as nearly as possible in the same azimuth and at nearly equal distances above and below. Its position is thus determined with great accuracy as the *difference* of two nearly equal distances. A zenith distance of about 60° is most suitable, as giving a large parallax factor and avoiding the uncertainties arising at low altitudes from bad definition and irregular refraction. The personal errors of measurement and the errors of scale will be eliminated if the comparison stars are nearly equidistant from the planet; the errors of the stars' positions will be eliminated if the same stars are used at the northern and the southern observatories; and the errors of the ephemeris will be eliminated if the northern and southern observations are simultaneous. It is not practicable nor even possible to satisfy all these conditions, but an important feature of this method is its "self-correcting" nature—"the observations themselves furnish the material for the determination and elimination of the errors to which it is liable."

The heliometer in use at the Cape, to which the others are in general similar, was made by Repsold, and is of 7 inches aperture and about 8 feet 6 inches focal length. A description of it, with drawings, is given at the beginning of vol. vii. The magnification used was 250 times; a reversing prism eye-piece was employed throughout. The object-glass scales are of irido-platinum and are divided to every $\frac{1}{2}$ mm., the divisions being figured 0 to 200 and 200 to 400 on the two scales. The divisions are very sharp and a magnifying power of 100 diameters is used in the reading microscope; the wires of this microscope are $1''\cdot 4$ apart, and the divisions can be clearly seen between them. The probable error of a pointing is given by Dr. Gill as $\pm 0''\cdot 02$. Divisions of the two scales are seen together: a division of one is bisected by the fixed wires of the micrometer and a division of the other by the

moveable ones. The readings are printed on a ribbon of paper, thus saving the observer the necessity of reading them, and preserving a permanent record available for the detection of errors.

The division errors of the scales were determined by comparing each of the 10 division spaces from 10 to 190 of the one scale with each of those from 210 to 390 of the other, the divisions of each scale being simultaneously under the same micrometer. In this way cumulative error in the determination is avoided. A similar method was afterwards applied to the single divisions. The determination of these division errors involved 50,000 pointings, and occupied two hours a day for nine months. The probable error of the value for each principal division is $\pm 0''\cdot 0048$, and for the other divisions $\pm 0''\cdot 0092$.

In the different series of observations a large number of measures of position angles have been made in addition to those of distance. Dr. Gill, however, finds that measures of distance can be made with much greater accuracy than measures of angle. The position angles are corrected in the usual way for errors of adjustment of the equatorial. In measuring distances no adjustment of focus is permissible during a set of observations, as this affects the scale, which is determined each night from measures of distances between two standard stars. Dr. Gill finds that the measures of distance require a correction of the form $s \, \Delta \, \sigma + \frac{1}{s} \mathrm{N}$. The first term is the scale correction; the second is a personal correction depending on the observer's method of making the star images pass through one another in his estimations of coincidence. It appears that with modern heliometers in which the field is illuminated the sign of this correction is always positive, whereas in the older instruments, without illumination of the field, it was negative. The cause of this correction is considered in detail by Dr. Gill. Any uncertainty in the determination of these coefficients is almost entirely eliminated in the results obtained from nearly equal double distances.

For the meridian observations of the comparison stars for the three planets Dr. Gill secured the co-operation of 22 different observatories. Altogether 9620 observations of 115 stars were secured, and their discussion was undertaken by Dr. Auwers, and is given in vol. vii. Generally speaking, a somewhat preponderating weight is given to one or two observatories, particularly in the case of *Sappho*, where a weight of 410 is given to 404 observations of right ascension made at Berlin, while a weight of 555 is given to 2614 observations made at 14 other observatories. The probable error of the results (considered as relative positions) is given as about $\pm^{s}\cdot 005$ or $\pm^{s}\cdot 006$ in R.A., and $\pm''\cdot 07$ or $\pm''\cdot 08$ in Decl. The proper motions of all the stars, though in many cases very small, are determined with great care by comparison with all previous observations which can be found. Systematic corrections are applied to the catalogues used in order to

bring them into harmony with A.G.C. system, except in the case of the declinations of the *Victoria* and *Sappho* stars which are reduced to Auwers' system of fundamental stars for the southern zone of the Astronomische Gesellschaft, and which is in close agreement with his previously determined "Mean System." In the discussion of the right ascensions, corrections for variation of personal equation with magnitude are applied to bring the different observatories into harmony with Berlin, and a short account is given of the experiments made with gauze screens to determine the absolute value of this correction. In all the series in which transits were recorded on the chronograph the right ascensions increase with diminishing brightness, but the amount of this increase appears to be only roughly determinable. Dr. Auwers remarks that the same tendency is observable with the "eye and ear" observations.

A triangulation of the forty-two stars used in the *Victoria* series was made from 1867 measures of distance and 151 of position angle, to strengthen the results of the meridian observations. The measures of distance were corrected for refraction, aberration, and scale, the last-named being determined each night by measures of the distance of the standard stars. The resulting distances were further corrected as follows: each observer's measure was compared with Dr. Gill's, and a linear correction was first obtained and applied to the distances to correct for any personality relative to Gill which he may have in making the measures of the brighter standard stars as compared with the ordinary comparison stars: the distances were now compared with the distances computed from the meridian observations, terms being inserted in the equations for magnitude corrections to the right ascensions. The solution of these equations gives the systematic corrections required by Gill for different distances and the coefficients of the magnitude corrections to be applied to the meridian right ascensions. Combining this with the previous comparison with Gill, the systematic corrections required by all the measurers are determined. These corrections are applied to the distances obtained by the several observers, which are next combined with their appropriate weights. By comparison with the distances determined from the meridian observations equations are now formed for every measured pair of stars to give corrections to the assumed right ascensions and declinations. These equations are easily solved for each star by successive approximations. As the result of the triangulation, Dr. Gill reduces the probable error of the right ascensions and declinations to about $\pm''\cdot 03$. In this investigation Dr. Gill arrives at the personal correction of heliometer measures of distance, varying inversely as the distance referred to above, but as the numerical values of the correction had been already found, he did not resolve his equations on this assumption.

The observations of *Victoria* were made from 1889 June 10, to August 26. Altogether 1627 observations of distance

and position angle were made. The observations of *Sappho* extended from 1889 September 18 to October 27. In the discussion only measures of double distances are used. *Iris* was observed from 1888 October 10 to November 17, and 1107 measures were made. The observations of *Victoria* and *Sappho* are discussed by Dr. Gill, those of *Iris* by Dr. Elkin. Equations are formed by comparing the measured distances with those computed from an ephemeris. The solution of these equations gives corrections to the ephemeris and a correction to the adopted parallax. In the cases of *Sappho* and *Iris* the corrections to the ephemeris must be regarded as more or less empirical, and their complete elimination is provided for in the discussion. In the case of *Victoria*, however, the triangulation of the comparison stars and the use of a more accurately computed ephemeris made it possible to determine the absolute positions of the planet with great accuracy. Examination showed that the corrections required by the ephemeris had a period of twenty-seven days, and that the maxima and minima occurred when the Moon's geocentric longitude differed 90° from that of the planet. This showed an error in the lunar equation of the Earth's motion, and furnished a correction to this term.

(A determination of the Sun's parallax from the meridian observations of *Victoria*, *Sappho*, and *Iris*, by Dr. Auwers, is also given. The results from the three planets are discordant, and the weight of the result is very small.)

The results of the three heliometer determinations are :

	π	Prob. Error.
From Victoria (Gill)	8″·8013	± ″·0061
Sappho (Gill)	8·7981	± ·0114
Iris (Elkin)	8·8120	± ·0090
Mean ...	8·8036	± ·0046

That these three independent results agree within the limits of their probable errors affords strong evidence that they are free from systematic error. Two possible sources of systematic error are briefly considered by Dr. Gill : (1) *Errors in the elements of the orbits.* For *Iris* Dr. Elkin found the effect of a difference in the log. distance between the ephemeris he used and that given in the Berlin ephemeris ; as the latter had correctly represented the observations of the planet for a considerable time it was assumed that it could not be much in error, and a correction ″·003 was applied to the parallax deduced by the use of an ephemeris which only represented the position of the planet during the opposition of 1888–9. The ephemerides of *Victoria* and *Sappho* have represented the observations for a considerable time, and it is therefore assumed that their elements require no correc-

tions of amount sufficient to affect the parallax. (2) *A difference in the mean refrangibility of the light of the planets and their comparison stars.* Professor Newcomb says: "If the difference between the spectra of a minor planet and a comparison star is such that the means of their respective visible spectra, or the apparent amounts of their respective refractions, differ by one-tenth of the space between D and E, an error of $0''\cdot02$ or $0''\cdot03$ may be produced in the apparent parallax of the planet." Dr. Gill remarks on this that it is impossible to distinguish *Victoria* and *Sappho* from the average fixed star of similar magnitude when they are placed near together in the field of the heliometer, and considers that a mean visual difference of colour much less than one-tenth of that between D and E would be readily distinguishable under such a test. Dr. Elkin remarked that the light of *Iris* was slightly less refrangible than that of the stars, but the difference of colour appears to have been very slight. Giving half weight to the *Iris* determination on this account, the value $\pi = 8''\cdot802$ with a probable error of $\pm''\cdot005$ is given as the final result of the discussion. With this value of the parallax the reciprocal of the mass of the Moon determined from the *Victoria* observations is $1/M = 81\cdot702 \pm \cdot094$.

Dr. Gill briefly criticises other methods of determining the Sun's parallax, and considers that it is not legitimate to use the aberration constant for this purpose till a satisfactory physical theory has been put forward. It may be argued, however, that the assumed law of aberration agrees sufficiently closely with the facts to warrant a belief in its *exact* truth, and if this view be taken, aberration furnishes an excellent method of obtaining the Sun's parallax, fairly comparable with Dr. Gill's purely geometric method.

In these two large volumes Dr. Gill has given full details of the numerous observations on which his research is founded, and a clear exposition of his methods. He is to be heartily congratulated on the highly satisfactory conclusion of his arduous undertaking.

The Constant of Precession.

In vol. vii. of the Astronomical papers prepared for the use of the American Ephemeris, Professor Newcomb makes a re-determination of the value of the precession from the proper motions Dr. Auwers obtained by comparison of his re-reduction of Bradley's observations with the Greenwich Catalogues of 1860 and 1865. Systematic corrections are applied to these proper motions to reduce them to the system of Newcomb's "Catalogue of 1080 Fundamental Stars," the most important part of the corrections to the right ascensions arising from $-{}^{s}\cdot079$ applied to the equinox of Auwers-Bradley and $+{}^{s}\cdot024$ applied to the Catalogues of 1860

and 1865. To obtain a criterion as to what stars had best be rejected on account of their large proper motions, a classification is made for stars of different magnitudes according to the size of their proper motions, and the number of stars in each class compared with the number there would be if the distribution were according to the least-squares law. Out of 3181 stars 654 are excluded, and Professor Newcomb concludes from the discussion that more than one-third of the Bradley stars have no proper motion except what is due to the movement of the Sun, and that nearly all of them are included in a sphere whose radius would correspond to a parallactic motion of 2″ per century. Several different methods of treatment are employed in view of the difficulty of eliminating the solar motion, and the possibility of groups of stars having a common proper motion. These methods give accordant results, as also do the stars of different magnitudes, but the result obtained from right ascensions is 1″ per century different from that obtained from declinations, and, further, the latter differs considerably from the result obtained by L. Struve from the same data.

Further examination fails to show any inaccuracy in the result derived from the declinations, which is accordingly accepted. The right ascension result can be made to agree more closely with this by assuming a common motion in right ascension for the fundamental stars; the Greenwich Sun observations, 1835–1895, give a value of about 0″·5 per century for this, and, balancing the evidence, a correction of 0″·30 is adopted.

The values finally obtained as compared with the values of Struve-Peters now in general use are for epoch 1850

	General Precession.	m	n
	″	″	″
Newcomb	50·2453	46·0711	20·0511
Struve-Peters	50·2522	46·0763	20·0564

Some discussion has taken place in the *Astronomical Journal* as to the wisdom of substituting Professor Newcomb's value for that of Struve-Peters in the National Ephemerides, as proposed by the Paris Conference of 1896 May.

Latitude Variation.

The motion of the pole deduced by Dr. Chandler from an exhaustive discussion of observations, irrespective of theory, has been resolved into a combination of two separate motions, one an annual motion from west to east of the terrestrial pole in a very eccentric ellipse about its mean position, the principal axis being 0″·30 and 0″·08, the major axis lying on a meridian

45° east of the Greenwich meridian, and the pole reaching the extremities of this axis on April 6 and October 5; the second is circular, with a period of 427 days and a variable radius. The elements of the annual period have been based entirely on recent data from observations between 1889·0 and 1894·0, while the elements of the second period have been derived from observations extending over the years 1825–90. In *Ast. Journ.*, No. 392, he has given a table of the motion of the pole for 1897 at Greenwich, Pulkova, Berlin, Paris, and Washington, and confidently predicts that when the observations made during this year are reduced, his theory will be found to agree within the limits of accuracy to be obtained by the most refined methods at a series of stations specially adapted for the purpose. In *Ast. Journ.*, No. 402, Dr. Chandler has discussed the series of observations specially made between 1894 January and 1895 August at Kazan, Potsdam, Karlsruhe, Strassburg, Bethlehem, and Columbia, and finds that the results conclusively prove the reality of the annual motion and its large eccentricity, and give no evidence of any progressive changes in its value. These latest observations likewise confirm the diminution in the value of the radius of the circular motion, the law for which was previously announced in *Ast. Journ.*, No. 322. Finally, in *Ast. Journ.*, No. 406, Dr. Chandler has placed in a succinct form the mathematical relations involved in the problem that a pole of rotation has a motion relative to the pole of figure, which may be resolved into two components, one an ellipse with a mean period of a year, the other a circle with a mean period of 428·6 days.

W. G. T.

Professor Barnard's Dimensions of the Planets.

While at the Lick Observatory, Professor Barnard made an extensive series of micrometrical measures of the planets. Many of these measures have been given from time to time in the *Monthly Notices*, the *Astronomical Journal*, and other publications, but the results so published have in some cases been preliminary values only. Professor Barnard has now collated and reduced his observations and in *Popular Astronomy*, No. 46, he gives the final adopted values of his measures. These are summarised in the following table :—

Name of Planet.	Diameter in seconds of arc.	Distance to which the diameters in arc are reduced, the mean distance Sun-earth being unity.	Diameter in English miles.
Mercury	6″·126	1	2,765
Venus	17·397	1	7,826
Mars (equatorial)	9·673	1	4,352
„ (polar)	9·581	1	4,312
Ceres	1·076	1	485
Pallas	0·675	1	304
Juno	0·263	1	118
Vesta	0·540	1	243
Jupiter (equatorial)	38·522	5·20	90,190
„ (polar)	36·112	5·20	84,570
Jupiter's Satellites:			
Satellite I.	1·048	5·20	2,452
„ II.	0·874	5·20	2,045
„ III.	1·521	5·20	3,558
„ IV.	1·430	5·20	3,345
Saturn (equatorial)	17·798	9·5389	76,470
„ (polar)	16·246	9·5389	69,780
„ outer diameter, outer ring	40·186	9·5389	172,610
„ inner „ „	35·034	9·5389	150,480
„ centre Cassini division ...	34·517	9·5389	148,260
„ outer diameter, inner ring	34·000	9·5389	145,990
„ inner „ „	25·626	9·5389	110,070
„ „ „ crape ring	20·528	9·5389	88,190
„ diameter of satellite Titan	0·633	9·5389	2,720
Uranus	4·040	19·1833	34,900
Neptune	2·433	30·0551	32,900

The measures of *Mercury* above given were made during the transits of 1891 and 1894 with the 12-inch refractor reduced in aperture to 4 inches in 1891, and to 5 inches and 6 inches in 1894. The measures of all the other planets and satellites were made with the 36-inch refractor.

The Atmospheres of Planets and Satellites.

In a paper "On the Physical Constitution of the Sun and Stars" in No. 105 (1868) of the *Proceedings of the Royal Society*, Dr. Johnstone Stoney applied the kinetic theory of gases to the

interpretation of some of the phenomena of atmospheres. He subsequently extended these investigations; and in a recent memoir published in the *Scientific Transactions of the Royal Dublin Society*, vol. vi. p. 305, "On Atmospheres upon Planets and Satellites," he has given an account of communications made to that Society, in which he explains the absence of hydrogen and helium from the Earth's atmosphere, and the absence of all known constituents of an atmosphere from the Moon, by showing that in accordance with the kinetic theory these gases are so circumstanced on the Earth and Moon that their molecules can drift away; and he further arrives at the conclusion that the same theory implies that the vapour of water cannot be a constituent of the atmospheres of either *Mercury* or *Mars*. The conditions which prevail upon *Mars* are specially discussed.

The investigation also offers an explanation of such a gap in the series of chemical elements as we find upon the Earth between hydrogen and helium, and between helium and lithium; and it shows that if the suspected intermediate elements exist, the conditions upon *Jupiter* are such that they may all be present in his atmosphere, and that some of them may be present upon *Saturn*, *Uranus*, and *Neptune*, though not upon any of the group of four smaller inner planets to which the Earth belongs.

By an application of the same method of investigation to the satellites and the minor planets of the solar system Dr. Stoney infers that there can be no atmosphere upon any of these bodies, except perhaps on the great satellite of *Neptune*.

Finally, the investigation leads to the conclusion that the molecules of the gases which have from time to time escaped from planets or satellites have but seldom been able to extricate themselves altogether from the solar system, and are accordingly for the most part now circulating round the Sun, like excessively minute independent planets.

Star Catalogues.

Auwers' Catalogue of Reference Stars for the Southern Zone Observations of the A.G.C.—In *A.N.*, No. 3431, Dr. Auwers has published a catalogue of "Anhaltsterne" for zone observations in the southern heavens. The catalogue, which is for the epoch 1900, contains 480 stars and 24 close polars, and extends from $-20°$ to the S. Pole. All available material from 1860 to 1895 has been used in its preparation. The adopted equinox is that of the A.G.C., and the declinations are reduced to the same system as the "Catalogue of 303 Fundamental Stars for Southern Zone Observations," already given by Dr. Auwers, which differs from the A.G.C. system by $+0''\cdot50-0''\cdot02\times\delta°$, and agrees closely with Auwers' Mean System, given in *A.N.*, No. 1536.

Gilliss' Catalogue of Southern Stars.—In the *Washington Observations* for 1890 is published a catalogue of 16,748 southern

stars for the epoch 1850. The observations for this catalogue were made under the direction of the U.S. Naval Observatory by Captain Gilliss during the years 1849–52. The stars observed are confined to the region within 25° of the S. Pole, and were made with a 4½-inch meridian circle by Pistor and Martins. The total number of observations is about 27,000, so that about half the stars have been observed only once, and not many more than twice. Captain Gilliss with a staff of computers worked at the reductions till his death in 1865, shortly after which the computations were stopped, and the papers remained untouched for twenty-five years in the U.S. Naval Observatory; and it was not till 1890, when Professor S. J. Brown and the late Professor Edgar Frisby were appointed to superintend the completion of the work, that efforts were made to deal with the accumulated material.

Catalogue de 382 Etoiles faibles de la Zone DM + 2°.—In the volume of *Brussels Observations* for 1896, Dr. L. de Ball has published a small catalogue of faint stars between 9·0–9·5 magnitudes, which were not re-observed in the *Astronomische Gesellschaft* Catalogue for the parallel + 2°. He started with the idea of extending his observations to all the stars in the *Bonn Durchmusterung* for these magnitudes, but finding that photography was a much better method for finding the places of such stars, he has relinquished his original design and published the results he has obtained.

Catalogo di 2491 Stelle Australi nel parallelo 20° Australe (1855.0) *Modena.*—For the same magnitudes Professors Millosevich and Peyra, at the Royal Observatory at Rome, have observed all stars between the parallels of −20° and −21° which had been previously observed in Schönfeld's zones. Between 1895 March and the end of 1896 over 5000 observations were made of some 2491 stars, which have been reduced to the epoch 1895, and published without any loss of time.

Cambridge Zone Catalogue.—This catalogue contains 14,464 stars between 24° 15′ and 30° 57′ N. declination. The transits were observed by the eye and ear method by Mr. Graham; the readings of the circle were made by Mr. Todd, two microscopes being used. As in the other zone observations of the *Astronomische Gesellschaft*, the right ascensions and declinations depend on those of standard stars. An account of the Catalogue is given in the Report of the Cambridge Observatory to the Council.

Catalogue de l'Observatoire de Paris.—The third volume of the *Paris Catalogue* (from 12^h to 18^h) giving the results of observations made at the Paris Observatory from 1837 to 1881, appeared during the year. The observations from 1837 to 1853 are reduced to the epoch 1845, those from 1854 to 1867 to the epoch 1860, and those 1868 to 1871 to the epoch 1875·0. The observations are compared with Lalande, and for those stars which show considerable differences the proper motions are deduced by extensive comparisons with a large number of catalogues.

Catalogue des Mouvements propres de 2641 *étoiles.*—In the *Annales de l'Observatoire de Paris* for 1888, published in 1896, M. J. Bossert has collected together a list of 2641 stars whose proper motions exceed $0^{s}.010$ in right ascension, and $0''.10$ in declination, and the observations of which extend over fifty years. M. J. Bossert appears to have exhausted all the most modern material for his compilation, so that his list may be considered quite up to date as far as it goes. The proper motions in right ascension are given to three, and in declination to two places, and in many cases are determined from three authorities, which are in all cases plainly stated. His avowed object in making the list is to draw the attention of astronomers to these particular stars, and astronomers can only be thankful to M. Bossert for the trouble and labour which has put in their hands such a useful desideratum.

W. G. T.

Double Stars.

The report is, as in former years, considered under the two heads—Observation and Calculation.

Observation.—First list of new pairs (78) discovered at the Cape Observatory by Mr. Innes with the 7-inch refractor ...	*A.N.* 3406
Second list of 149 new pairs	*M.N.* May
Third list of 60 new pairs	*A.N.* 3438
Fourth list of 29 new pairs...	*A.N.* 3462
α Phœnicis, π Phœnicis, μ Velorum, β Lupi, η Centauri announced double by Dr. See	*P.A.* March
Mesures micrométriques d'étoiles doubles faites à St-Pétersbourg et à Domkino, by Professor Glasenapp in 1895	
Measures of 86 pairs with 36-inch Lick Refractor by Professor Hussey	*A.J.* 397
„ „ 32 Struve pairs with 12-inch refractor at Morrison—Pritchett (1896)	*A.J.* 397
„ „ 8 wide pairs by M. Eichelberger	*A.J.* 397
„ „ 92 special pairs with 10½-inch at University Observatory, Minnesota—Leavenworth ...	*A.J.* 407
„ „ 25 pairs—S. B. Saulè, ditto ...	*A.J.* 410
„ „ 3 pairs—Mary Wagner, ditto...	*A.J.* 410
„ „ 26 pairs, whose orbits appear in Dr. See's "Evolution of Stellar Systems," by Eric Doolittle with 18-inch at Flower Observatory ...	*A.J.* 416

Measures of 56 wide pairs (OΣ^2)—Franz ...	*A.N.* 3464
,, ,, Struve pairs by MM. Charfordet and Petit (Besançon) ...	*A.N.* 3450; *B.A.* 1897 Nov.
,, ,, 31 pairs by J. L. Scott ...	*B.A.J.* vii. 2
,, ,, 13 Struve pairs by Lehman with 12-inch Lick Refractor ...	*A.S.P.* No. 56
,, ,, double stars in the cluster surrounding η *Carinæ*—T. J. J. See	*M.N.* May
,, ,, 8 pairs—Mr. Tebbutt... ...	*M.N.* June
,, ,, a large number of pairs by Aitken at Lick	*A.N.* 3465–6
,, ,, pairs by Dr. Doberck ...	*A.N.* 3465–6
,, ,, small stars near *Sirius*—Barnard	*A.J.* 420
,, ,, companion to *Sirius*—Schæberle	*A.J.* 394, 420
,, ,, ,, ,, Aitken...	*A.J.* 415; *A.S.P.* 55, 59
,, ,, ,, ,, See ...	*A.J.* 418; *A.N.* 3469
,, ,, ,, *Procyon*—Schæberle	*A.J.* 394, 416, 420
,, ,, ,, ,, Aitken...	*A.J.* 394; *A.S.P.* 54
,, ,, ,, ,, Hussey...	*A.S.P.* No. 56
,, ,, β 883 and β 552 Aitken...	*A.S.* 415
,, ,, β 733 Schæberle	*A.J.* 420
,, ,, companions to *Vega*—Barnard	*A.J.* 414
,, ,, ,, ,, Schæberle	*A.J.* 418
,, ,, 70 *Ophiuchi* Pritchett	*A.J.* 411
,, ,, ,, ,, Schur ...	*A.N.* 3405
,, ,, ,, ,, See ...	*A.J.*

Calculation.—The following orbits have been computed during the year:—

	Period.	Semi-axis Maj.	Reference.
Sirius	51·8	7·62	*M.N.* April
β 883	5·5	0·76	*M.N.* June
β 395	16·3	0·57	*A.N.* 3455
μ^2 Boötis	275·7	1·48	*A.N.* 3441
OΣ 400	85.		*M.N.* Jan. 1898

and other works are:—

The orbit of *Sirius* compared with recent Observations—T. J. J. See	*A.J.* 418
Note on the orbit of *Sirius*—Mann ...	*P.A.* March
Note on the pair 44 *Boötis*—Burnham ...	*M.N.* March
,, ,, δ *Cygni* ,, ...	*M.N.* April

Note on the pair	μ *Draconis*	Burnham	...	*M.N.* May
„ „	ζ *Boötis*	„	...	*M.N.* Jan. 1898
„ „	OΣ 215	„	...	*P.A.* April
„ „	Σ 1687	„	...	*P.A.* April
„ „	λ *Cygni*	„	...	*P.A.* Feb.
„ „	Σ 2909	„	...	*P.A.* March
„ „	OΣ 4	„	...	*P.A.* July
„ „	Σ 1216	„	...	*P.A.* Jan. 1898
„ „	Σ 2107	„	...	*P.A.* Jan. 1898
„ „	ξ 3638	See	...	*M.N.* March
„ „	γ *Lupi*	„	...	*M.N.* Nov.
„ „	ξ 5014	„	...	*M.N.* Dec.
„ „	ξ 4707	Innes	...	*Obs.* Oct.
„ „	κ *Toucani*		...	*M.N.* April
„ „	ξ 3941 and Stone 3480		...	*B.A.J.* vii. 9
„ „	ξ 4935		...	*M.N.* Jan. 1898
Remarks on double stars discovered at Arequipa—Innes			...	*A.J.* 417
General remarks on double stars			...	*Obs.* May
The spectra of binary stars...			...	*Obs.* March

The abbreviations are :—

M.N. Monthly Notices R.A.S.
A.N. Astronomische Nachrichten.
A.J. Astronomical Journal.
P.A. Popular Astronomy.
Obs. The Observatory.
B.A.J. Journal of the B.A.A.
A.S.P. Journal of Astron. Society of the Pacific.
B.A. Bulletin Astronomique.

T. L.

Variable Stars.

During the year the progress in this branch of astronomy has been very marked. If we consider merely the number of new variables discovered, the amount is out of all proportion greater than that discovered in any former year.

The Harvard Observatory announces in *Astronomische Nachrichten*, No. 3444, the discovery of no fewer than 310 variable stars in certain southern globular clusters. In one of the clusters, Messier 3, there is stated to be 113 variable stars—that is, one-ninth of the whole number of stars in the cluster is variable. It is to be hoped that close and continuous observation will be made of all these variables to determine if there be any similarity of period, amplitude or type of variation.

Professor Pickering, in *Ast. Nach.* No. 3422, announces the discovery of three southern variables, the variation being detected by examination of their spectra.

From the Cape Observatory we have during 1897 the announcement of sixteen new variables; the variation being discovered, in the first instance, either by a comparison of the magnitudes in the Cape *Photographic Durchmusterung* and the

Cordoba *Durchmusterung*, or by examination of Cape photographic plates taken at different dates.

In nearly every instance independent confirmation of variation by visual estimates is certified by Mr. R. T. A. Innes, who, in this branch of astronomy, as well as in the discovery of double stars, has done work conspicuously characterised by accuracy and zeal. Detailed information concerning the stars is to be found in *Ast. Nach.*, Nos., 3426, 3441, 3447, 3453.

Mr. Stanley Williams, in *Ast. Nach.*, Nos. 3,440, 3,450, gives a list of thirteen southern stars which observations made by him in 1885–1886 indicate to be variable. A comparison between the magnitudes recorded in the Southern Meridian Photometry and the magnitudes recorded in the *Uranometria Argentina* goes far to confirm the variation of several of these stars.

Dr. Thos. D. Anderson announces in *Ast. Nach.*, Nos. 3394, 3433, 3440, 3461, 3463, and 3467, the discovery of seven new variables. The variation of two of these stars—one in the constellation *Andromeda* and one in *Hercules*—has been confirmed by Parkhurst and Yendell.

The announcement is also made of the discovery of a new variable in *Virgo* by Mr. Arthur J. Roy, and one in *Puppis* by Mr. Arthur C. Perry.

Professor F. Deichmüller, in *Ast. Nach.*, No. 3447, gives particulars of a new variable in *Lacerta*.

A valuable link between the Cordoba observations (1871–78) of southern variable stars and those made in recent years is furnished by Mr. Stanley Williams, who, in the *Astronomical Journal*, No. 417, gives his observations of southern variable stars made in 1885 and 1886.

Mr. Williams also brings forward an interesting fact concerning the southern variable Lac 3105. Mr. Williams, on announcing the variation of the star some years ago, gave as its period 4½ days. Subsequent observation by other observers indicated a much shorter period than this. In *Ast. Nach.*, No. 3391, Professor Pickering announces that he finds Lac 3105 to be a spectroscopic binary with a period of 3·115 days; and Mr. Williams in No. 3410 states that half this period, or 1·558 days, will satisfy all his observations.

In the *Astronomical Journal*, No. 413, Mr. W. E. Sperra confirms the discovery made at Harvard as to the non-Algol nature of the variation of *S Antliæ*.

This star must now definitely be considered as belonging to the short period (II.) class.

Important definitive determinations of the light changes of β *Lyræ* and η *Aquilæ* have been made during the year. In the *Koninklijke Akademie van Wetenschappen te Amsterdam*, vol. v. No. 7, Herr Pannekoek gives the results of his investigations of β *Lyræ*.

He finds the following elements of principal minima :—

$$1855 \text{ Jan. } 6{\cdot}604 \text{ G.M.T.} + 12{\cdot}908009 \text{ E} + 0{\cdot}000003855 \text{ E}^2 - 0{\cdot}000000000047 \text{ E}^3.$$

The times between the principal phenomena of the light changes are as follows :—

	1842-1870. d	1870-1895. d
From Prin. Min. to 1st Max.	3·12	3·32
to 2nd Min.	6·40	6·48
to 2nd Max.	9·54	9·73

These facts would seem to indicate an almost circular orbit. In connection with this investigation must be mentioned the important spectroscopic researches on the orbital motion of the star by M. Belopolsky. M. Belopolsky finds that the radial velocity is zero when the star is passing either through its primary or secondary minimum. This conclusive proof of the chief cause of the variation of β *Lyræ* is most satisfactory. The smallness of the eccentricity found is also in keeping with the practically equal periods between the two maxima and two minima.

A definitive determination of the variation of η *Aquilæ* has been completed by Dr. W. J. S. Lockyer, who finds the light period to vary between $7^d\ 4^h\ 14^m\ 40^s$ and $7^d\ 4^h\ 13^m\ 28^s$ in 2400 periods. Dr. Lockyer also finds a decided oscillation in the time of maxima to the extent of 5 hours with a period comprising 400 maxima.

As in the case of β *Lyræ* we have recently a spectroscopic investigation of the orbital movement of η *Aquilæ* by M. Belopolsky. The investigation is to be found in the *Memorie della Società degli Spettroscopisti Italiani*, No. 7. Two important conclusions follow from this investigation. If both η *Aquilæ* and δ *Cephei*, typical stars of the short-period class, be binaries, duplicity is common to the whole class. Further, M. Belopolsky finds that in η *Aquilæ*, as in δ *Cephei*, the zero of radial velocity does *not*, as it does in the case of the Algol star β *Lyræ*, take place when the star passes through its minimum phase. Eclipse accordingly is not the primary cause of the star's variation. The higher eccentricity of these two stars, the maximum phase taking place soon after periastron, point clearly in the direction to which we must look for an explanation of the phenomenon of short-period variation.

The variable star observations of the late Mr. George Knott, comprising observations of 23 variables, are now in the press, and will form a volume of the *Memoirs* of the Society.

A. W. B.

Spectroscopic Astronomy in 1897.

An announcement made by Professor E. C. Pickering in 1897 January will probably make the year memorable in the history of spectroscopes, inasmuch as it deals with a discovery which promises to lead to an extension of our knowledge of the spectrum of hydrogen.

Pickering had previously announced that in the spectrum of the star ζ *Puppis* there was, in addition to the well-known series of hydrogen lines, a rhythmical series of lines of unknown origin. In his later note (*Astrophysical Journal*, vol. v. p. 95) he points out that the wave-lengths of the lines of the new series are connected by a formula of the usual type, and moreover that a formula can be found which is identical with that connecting the wave-lengths of the hydrogen lines; the new series being deduced by taking odd values of n, the known (hydrogen) series by taking even values. The new lines alternate with the hydrogen lines, and the new series converges to the same point in the ultra violet as the hydrogen series. Professor Pickering's expectation, that the new series are attributable to hydrogen, is already shared by many authorities in spectroscopy. The search for means of exciting in the spectrum of terrestrial hydrogen the new series of lines will be doubly interesting, for it seems not unlikely that it may lead to the discovery of yet another series of lines—the "principal" series of hydrogen.

An important paper (*Proc. R. S.* vol. lxi. pp. 148–209) by Sir Norman Lockyer was made the subject of a discussion at the Royal Society towards the end of February. The paper is an elaboration of the author's view that in the evolution of stars as evidenced by their spectra "the only variable of paramount importance is temperature" (*loc. cit.* p. 150). From a study of the admirable photographs of stellar spectra obtained at South Kensington, Lockyer is led to conclude that if the spectra of different stars are arranged in order of the extension of the continuous spectrum with the ultra violet—that is, in order of temperature, according to the usual view—then a regular sequence in the appearance and disappearance of the absorption lines of certain elements may be traced. The lines of the cleveite gases appear only in the spectra of stars which exhibit great extension of continuous radiation into the ultra violet. A diminution of the extension into the ultra violet is accompanied by a weakening of the lines of the cleveite gases and a relative intensification of certain metallic absorption lines which Lockyer has called enhanced lines. With a further diminution of the extension into the ultra violet the enhanced lines die out, and the metallic absorption lines corresponding with the ordinary arc spectra of the metals become prominent. The enhancement of lines in passing from the arc spectrum to the spark spectrum of a metal is ascribed by Lockyer to the difference of temperature; and he finds that the order of temperature of certain stars, as determined

from a comparison of the extensions of the continuous spectrum is the same as that which follows from a comparison of the metallic spectra at four stages of temperature—viz. the temperature of the flame spectrum, of the arc spectrum, of the spark spectrum, and of a spectrum consisting solely of those lines which are enhanced in passing from the arc to the spark. It is beyond the scope of the present note to do more than record in the briefest manner the publication of Sir Norman Lockyer's very suggestive paper.

An abstract of the remarks made by Professor Schuster in the course of the discussion is published in the same number of the *Proceedings of the Royal Society*, and forms an exceedingly valuable commentary on the paper.

Father Sidgreaves makes another valuable contribution to the study of the spectrum of β *Lyræ* (*Monthly Notices*, vol. lvii. pp. 515–531), giving special attention to thirteen lines or groups of lines in the spectrum. This work has been accomplished with the Father Perry Memorial instrument at the Stonyhurst College Observatory. Eighty-eight photographs of the spectrum, taken between 1895 May and November, are utilised in the discussion, and the varying behaviour of the bright lines is noted with respect to the time-interval from the preceding principal minimum in the cycle of the star's variation of brightness. The difference in the behaviour of the two hydrogen lines $H\beta$ and $H\gamma$ seems to deserve further attention.

A remarkable piece of work, forming part of the Henry Draper Memorial, has recently appeared—viz. vol. xxviii., Pt. 1, of the *Annals of the Harvard College Observatory*. It contains the results of the examination (carried out by Miss A. C. Maury, under the direction of Professor E. C. Pickering) of 4800 photographs relating to the spectra of 681 bright stars north of declination $-30°$, and forms a new classification of stellar spectra. The spectra are arranged in a progressive series of twenty-two groups, starting with stars of the *Orion* type, and passing by almost insensible steps through five types.

In the publication of a short note in June on "Some determinations of velocity in the line of light," Mr. H. F. Newall has given (*Monthly Notices*, vol. lvii. pp. 567–577) a sign of the successful inauguration of an important piece of work at the Cambridge Observatory. The determinations have been made from photographs, the stellar spectra being photographed between iron comparison spectra. Examples of results are given in the paper, and a comparison with Dr. Vogel's work, in which hydrogen was used for the standard line, shows that the different methods lead to the same result.

In a paper read before the Royal Society in June, Sir William and Lady Huggins describe a set of experiments which show that by sufficiently diminishing the quantity of calcium on two terminals between which an electric spark passes, the spectrum of the spark may be reduced, so far as calcium is concerned, to a

spectrum of two lines corresponding with the lines H and K. This experimental result, taken in connection with the fact that the lines H and K are the sole representatives of the calcium spectrum in many extensive prominences, constitutes a definite advance in solar physics. It has long been recognised that by decreasing the *quantity* of incandescent vapour the number of lines in the spectrum of an element may be reduced till only one or two lines are visible, but it appears that it has never been actually determined which line or lines are the most persistent in the case of calcium.

The Longitude of Madras.

Warren's Longitude of Madras, on which the longitudes of the Indian Survey Maps depend, is known to be about $2\frac{1}{2}'$ too large, and a re-determination by Captains S. G. Burrard and Lenox Conyngham, who had been engaged in determining the astronomical longitudes of certain stations in Persia, was made in the year 1895. The difference of longitude of Greenwich and Karachi, a principal western station of the Indian Survey, whose longitude west of Madras is therefore well known, was published in 1897.

The arcs which make up the chain will be seen from enumeration of the following observing stations: Karachi, Bushire, Teheran, Potsdam, Greenwich. Besides these, Jask, on the Persian Gulf, was also a station, and the arcs Karachi—Jask, Jask—Bushire were determined, so that, as these three stations form a circuit, a check is supplied to the determination of the arc Karachi—Bushire. Noteworthy points about this chain are, first, that the arc Teheran to Potsdam is very long, remembering that these places were connected almost entirely by a land line. The actual length is 2626 miles of land line, with two miles of cable inserted, and on this long line only one translation by relay was made. It was a little unfortunate, Captain Lenox Conyngham points out, that this had to be at Odessa, which is by no means the middle point of the line. The other point is that between Potsdam and Greenwich no relays were used, but the land lines were joined direct to the cable at Emden and at Lowestoft. It was suggested by Mr. Preece, the Engineer-in-Chief of the Post Office, that not only would this arrangement be possible, but that by having lengths of land line at either end of the cable the retardation time would be more likely to be the same in both directions than if the cable were joined to a single land line. This consideration, as well as a suggestion by the Astronomer Royal that it would be advisable to make Potsdam a station, induced Captain Burrard to modify the chain originally planned, in which the eastern stations were Greenwich, Lowestoft, Emden, Odessa.

It is not necessary here to follow the details of the work,

beyond saying that on the arc Potsdam—Greenwich the observers interchanged stations, so that the value of this arc is free from personal equation, if we may assume that neither observer changed his habit during the work. In determining the arcs Teheran—Potsdam, Teheran—Bushire, Captain Lenox Conyngham was in both cases at Teheran, so that the algebraic sum which gives the difference of longitude between Bushire and Potsdam is also not affected by personality, and although on the arc Karachi—Bushire personality was not eliminated, as has been said, this arc forms part of a circuit, and its value is therefore determined with additional weight.

The whole work, including in it the value of the arc Madras—Karachi from the volumes of the Indian Survey, gives as the longitude of Madras east of Greenwich $5^{h}\ 20^{m}\ 59^{s}{\cdot}113$ with a probable error $\pm 0^{s}{\cdot}0227$, which shows the error of the Indian triangulation to be $+2'27''{\cdot}54$. There are now five telegraphic determinations of the longitude of Madras, the results of which it may be of interest to compare. The first of these was partly made by the English observers of the transit of *Venus* in 1874, who determined the longitude of Suez from Greenwich. The arc from Suez to Madras was measured later by officers of the Indian Survey. About the same time the German observers of the transit of *Venus* with General Addison at Karachi and Mr. Pogson at Madras measured a chain *via* Ispahan and Berlin. Subsequently Dr. Gill and Dr. Auwers measured the arc Aden—Berlin, which with the before-mentioned links, Berlin—Greenwich and Madras—Aden, complete another chain. A fourth value results from a Russian determination of the longitude of Vladivostok combined with a series of arcs connecting that place with Madras, measured by officers of the U.S. Navy. The first results of these—for it should be said that all have been modified by subsequent discussion—are as follows:—

	Route *via*	h	m	s
(A)	Suez and Aden	5	20	59·416
(B)	Berlin and Ispahan	5	20	59·65
(C)	Berlin and Aden	5	20	59·041*
(D)	Pulkowa and Vladivostok	5	20	59·750
(E)	Present determination	5	20	59·113

The later discussions of the same chains result as follows:—

		h	m	s			h	m	s
(A)	...	5	29	59·422	(C)	...	5	20	59·233†
(B)	...	5	29	59·01†	(D)	...	5	20	59·452‡

As some explanation of the large differences shown by these results, it may be said that the arc by Dr. Gill and Dr.

* Copeland's reduction. † Auwers's reduction.

‡ This value was found by Professor Oudemans from comparison with the results of other chains, and is therefore not independent.

Auwers which forms a link of (C) was measured under circumstances of some difficulty, and this and the difference Greenwich—Suez of the chain (A) were determined by methods that were expected to give results of only minor weight. The chain (D) is the sum of a great number of links by different observers. Remembering that the recent determination was made by the same two observers throughout the chain, in few steps and with the utmost care, it is entitled to much weight in any discussion.

The value of the single arc Potsdam—Greenwich determined by Captain Burrard and Captain Lenox Conyngham is $0^h\ 52^m\ 15^s{\cdot}929$. The value of the longitude of Berlin east of Greenwich determined by German observers was $0^h\ 53^m\ 34^s{\cdot}910$, and the difference of longitude between Berlin and Potsdam has recently been determined with internal evidence of much accuracy as $1^m\ 18^s{\cdot}721$, so that compared with these the above value Potsdam—Greenwich is small by $0^s{\cdot}260$.

H. P. H.

The Yerkes Observatory.

The observatory attached to the University of Chicago, which takes its name from its generous donor, Mr. Charles T. Yerkes, was handed over to the University and formally opened with some ceremony in October 1897. The account of its origin, and of its building and equipment which follows, is mainly abstracted from a series of articles by Professor G. E. Hale, the Director of the Observatory, which appeared in the *Astrophysical Journal*.

The University of Chicago is not of great antiquity. When it began its work in 1892, it was felt that the study of astronomy and astrophysics should form part of its curriculum, and that an effort should be made to procure an observatory. There were then in the workshops of Messrs Alvan Clark two large discs of optical glass of 42 inches diameter, which had been provided to make a large objective for the University of Southern California, but for certain reasons this order had not been completed. Mr. Yerkes, at the suggestion of Mr. Hale, took the opportunity thus offered of procuring a very large object-glass without much delay. He bought the discs, gave orders for these to be fashioned into an objective of 40 inches diameter, and for a suitable tube and equatorial mounting to be made, and then with magnificent generosity, offered this complete instrument, together with the cost of a large observatory building, to the University. Needless to say, the offer was accepted, and after much careful consideration a site was chosen about seventy-five miles from Chicago, on the shore of Williams Bay, Lake Geneva, Wisconsin.

The first excavations for the building were made in 1895

April, and the staff were in residence by 1896 October. The ground floor of the building takes the form of a Latin cross, the central line of which lies east and west, and is 326 feet long. The western end of the central building is formed by the tower supporting the large dome, 90 feet in diameter, which covers the large equatorial; at the other end of the building is the transit room. The transept, very near the eastern end, is terminated at each end by towers, of smaller diameter but higher than the western, which are to carry smaller domes and equatorials. The architecture of the building, for which Mr. Cobb, of Chicago, is responsible, is of Moorish or Saracenic style. The slender pillars and elongated semicircular arches give a light appearance to the huge building, and the domes, which are usually difficult objects to deal with from an artistic point of view, harmonise well with the style of architecture.

To the interior details it is only necessary to refer briefly here. There is an elegant central hall, a heliostat room (which forms the attic of the transept before mentioned), spectroscopic, chemical, and optical laboratories, an instrument shop, photographic rooms, library, and other adjuncts of an observatory. The transit room, which is designed after the pattern of that at the Royal Observatory, Berlin, has walls of double sheet iron with an air space between. For architectural effect, this has an outer casing of a row of columns supporting a rich terra-cotta cornice.

The principal telescope is the 40-inch equatorial. The object-glass for this, made by Messrs. Alvan Clark & Son from the discs furnished by Mantois, of Paris, has focal length of nearly 62 feet. The crown lens is about $2\frac{1}{2}$ in. thick at the centre, and $\frac{3}{4}$ in. at the edge; it weighs 200 lbs. The flint lens, separated from the crown by a distance of $8\frac{3}{8}$ inches, is about $1\frac{1}{2}$ in. thick at the centre, 2 in. at the edge, and weighs over 300 lbs. The lenses are mounted upon aluminium bearings in a cast-iron cell. The mounting and rising floor were made by Messrs. Warner & Swasey, of Ohio. The column supporting the equatorial head is of cast iron, and the height of the top of the head above the lowest position of the rising floor is 43 feet. The polar and declination axes are of hard forged steel, and weigh $3\frac{1}{2}$ tons and $1\frac{1}{2}$ ton respectively. The polar axis is $13\frac{1}{2}$ feet long, and the declination axis $11\frac{1}{2}$ feet. The telescope tube, of sheet steel, is 52 inches in diameter at the centre, 42 inches at the objective end, and 38 inches at the eye end. The instrument is driven by a weight clock, which is wound automatically by an electric motor when the weight is near the limit of its fall, and the clock is controlled by a double conica pendulum. The instrument is supplied with a system of electro-motors to work the slow-motion gear and to clamp and unclamp the telescope, so that the telescope can be controlled with ease by the observer at the eye end. The accessories of the telescope are at present a filar micrometer, the solar spectroscope and spectro-heliograph formerly used at Kenwood, and a stellar spectrograph made by Mr. Brashear.

The other instruments of the observatory consist of the twelve-inch refractor with visual and photographic objectives, which is mounted in the north-east tower, a four-inch concave grating, a clock, and a collection of minor apparatus used at Kenwood. To this it is proposed to add a sixteen-inch refractor which will be placed on the north-west tower and used for micrometric work, and a transit instrument. An equatorially mounted portrait lens is to be set up in a small outbuilding for photographing such objects as comets and nebulæ, and it is proposed to make a sixty-inch mirror in the optical shop of the observatory, which, like the machine shop, is furnished with an elaborate and efficient equipment.

The following gentlemen constitute the observatory staff:—Professor G. E. Hale, Director; Professors Barnard, Burnham, and Wadsworth, with Mr. G. W. Ritchey in charge of the workshops. The programme of work, as at present arranged, is to a great extent spectroscopic and astrophysical, but micrometrical work on double stars, planets, and satellites has a place.

H. P. H.

Papers read before the Society from March 1897 to January 1898.

1897.

Mar. 12. On the mean motion of lunar perigee and node. E. W. Brown.

On the theoretical values of the secular accelerations in the lunar theory. E. W. Brown.

New double stars found at the Cape Observatory in 1896. Communicated by Dr. D. Gill.

Observations of comets and planets made with the Dun Echt refractor and wire micrometer at the Royal Observatory, Edinburgh, by Dr. J. Halm. Communicated by Dr. R. Copeland.

Micrometrical measures of double stars. W. Coleman.

The nuclei of a sun-spot. T. K. Mellor.

On a new binary of short period in the constellation *Dorado*. T. J. J. See.

Observations taken at Vadsö during the total eclipse of the Sun, 1896 August 9, by passengers of the S.S. *Neptun*. Drawn up and communicated by the Rev. T. C. Porter.

The orbit of δ *Cygni*. S. W. Burnham.

On the curve $y=\left\{\frac{1}{x^2+\sin^2\psi}\right\}^{\frac{3}{2}}$, and its connection with an astronomical problem. Mrs. W. H. Young (Miss Grace Chisholm).

Discordances of index errors of the Madras Mural Circle during the years 1834 to 1842 inclusive. A. M. W. Downing.

On a photographic transit-circle. H. H. Turner.

Further proof of the rotation-period of *Venus*. Percival Lowell.

The spectrum of β *Lyræ* as observed at Stonyhurst College Observatory in 1895. Rev. W. Sidgreaves.

Cloud statistics for stations in India near the path of the Moon's shadow on 1898 January 21–22. A. M. W. Downing.

Ephemeris for physical observations of *Mercury*. A. Marth.

Estimations of the magnitude of *Nova Aurigæ* made at the Radcliffe Observatory, Oxford. E. J. Stone.

Transit-circle observations of Comet Swift (1896 April 13) sub polo, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Attempt to photograph the *Leonids* in the open sky. Isaac Roberts.

Apr. 9. A new quadruple stellar system. R. T. A. Innes.

On the straightness of spider lines. H. H. Turner.

Observations of minor planet (8) *Flora* at Windsor, New South Wales. John Tebbutt.

The orbit of *Sirius*. S. W. Burnham.

Micrometrical measures of the double stars in the great nebula and cluster surrounding *η Carinæ*, made with the 24 inch refractor of the Lowell Observatory. T. J. J. See.

On some original observations of the comet of 1652. E. B. Knobel.

On the determination of the epoch-correction of an adopted system of right ascensions of clock stars from observations of the Sun, including the effects of personalities; and applications of the results to the determination of the errors of the tables of the Sun and Moon. E. J. Stone.

An investigation concerning the position error affecting eye estimates of star magnitudes. A. W. Roberts.

Proper motion of the southern short period variables *L Carinæ* and *K Pavonis*. A. W. Roberts.

On the apparent disc and on the shadow of an ellipsoid. A. Marth.

Observations of comets 1896 III. (Swift), and 1896 IV. (Sperra), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

An improvement in winding equatorial clocks. A. F. Lindemann.

May 14. Preliminary note on a personal equation depending on magnitude affecting the right ascensions of the stars in the Cambridge Zone Catalogue of the *Astronomische Gesellschaft* and its determination from Astrographic Catalogue plates. A. R. Hinks.

Zodiacal radiants of fire-balls. W. F. Denning.

On a new binary star with a period of five and one half years. (*β* 883). T. J. J. See.

On the mean places and proper motions for 1900 of 24 southern circumpolar stars. David Gill.

On the determination of terrestrial longitudes by photography. Capt. E. H. Hills.

The orbit of *μ Draconis*. S. W. Burnham.

Observations of comets Perrine 1896 Nov. 2, and Perrine 1896 Dec. 8, made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Cometary observations at the Liverpool Observatory, 1896. W. E. Plummer.

On the various forms of personal equation in meridian transits of stars. T. H. Safford.

June 11. Theory of the motion of the Moon. E. W. Brown.

Note on the mean motions of the lunar perigee and node. E. W. Brown.

Elements of comet Perrine (*f*) 1896, Nov. 2. C. J. Merfield.

Nebula H I. 43 *Virginis*. K. D. Naegamvala.

The expected shower of *Leonids* in 1897. W. F. Denning.

Results of double star measures with the 8-inch equatorial at Windsor, New South Wales, in 1896. John Tebbutt.

Notes on the reduction of stellar photographs. A. A. Rambaut.

Photographic observations of comet (*b*) 1896. A. A. Rambaut.

Ephemeris for physical observations of the Moon. A. Marth.

On some spectroscopic determinations of velocity in the line of sight made at Cambridge Observatory. H. F. Newall.

Nov. 12. The effect of the general illumination of the sky on the brightness of the field at the focus of a telescope. F. L. O. Wadsworth.

A note on spider lines. F. L. O. Wadsworth.

Catalogue No. 2 of nebulæ discovered at the Lowe Observatory, Echo Mountain, California. Lewis Swift.

Occultation of *Ceres* by the Moon on 1897 November 13, visible at Greenwich. Communicated by the Superintendent of the *Nautical Almanac*.

Personality in measurements of photographs for the Astrographic Catalogue at the University Observatory, Oxford. H. H. Turner.

Observations of *Jupiter* and *Jupiter's* satellites made at Mr. Crossley's Observatory, Bermerside, Halifax. J. Gledhill.

Observations of the physical features of *Mars* made at Mr. Crossley's Observatory, Bermerside, Halifax, during the opposition 1896–97. J. Gledhill.

Note on observations of *Venus* in 1897 (January to April), at Mr. Crossley's Observatory, Bermerside, Halifax. J. Gledhill.

List No. 3 of nebulæ discovered at the Lowe Observatory, Echo Mountain, California. Lewis Swift.

On the nature of the orbit of γ *Lupi*. T. J. J. See.

List No. 4, for 1900·0 of nebulæ discovered at the Lowe Observatory, California. Lewis Swift.

Equatorial Comparisons of *Uranus* with 41 *Libræ*, and a probable occultation of the star by the planet. John Tebbutt.

On the effect of chromatic dispersion of the atmosphere on the parallaxes of α *Centauri* and β *Orionis*; and on a method of determining its effect on the value of the solar parallax derived from heliometer observations of minor planets. David Gill.

The great equatorial current of *Jupiter*. A. Stanley Williams.

Approximate ephemeris of the *Leonids* from 1897 December 24 to 1898 April 8. G. Johnstone Stoney.

A spectroscopic method for determining the second and third contacts during a total eclipse of the sun. William Shackleton.

Occultation of the *Pleiades*, 1897 July 23. W. E. Plummer.

Note on a result concerning diffraction phenomena used by Professor Wadsworth in several recently published papers. H. F. Newall.

On the apparent diurnal motion of stars in relation to the adjustment of the polar axis of a telescope. C. Davidson.

Observations of comet *b* 1897 (Perrine) at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Dec. 10. Occultation of *Ceres* by the Moon on 1897 November 13, observed at the Hamburg Observatory. G. Rümker.

Ephemeris for physical observations of *Jupiter*, 1897–98. A. C. D. Crommelin.

A determination of the latitude variation and of the constant of aberration from observations made at the Royal Observatory, Cape of Good Hope, 1892–94. W. H. Finlay.

The binary star *h* 5014. R. T. A. Innes.

Mean areas and heliographic latitudes of sun-spots in the year 1895, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Additional note on personal equation. T. H. Safford.

Proper motions of the three close polar stars Groom-

bridge 1119, 2283, and 3548. Communicated by the Astronomer Royal.

Observations of meteors on 1897 November 13–15, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Occultation of the planet *Ceres* by the Moon on 1897 November 13. Communicated by the Radcliffe Observer.

1898.

Jan. 14. The ternary system Lac. 7215 = *h* 4935. R. T. A. Innes.

The double star *ζ Boötis*, Σ 1865. S. W. Burnham.

The orbit of OΣ 400. S. W. Burnham.

A note on the result concerning diffraction phenomena recently criticised by Mr. Newall. F. L. O. Wadsworth.

Observations of occultations of stars by the Moon, and of the phenomena of *Jupiter's* satellites, made in the year 1897 at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Occultations of the *Pleiades* by the Moon on 1897 July 23 and 1898 January 3, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Ephemeris for physical observations of *Jupiter*, 1898. A. C. D. Crommelin.

On the parallax of *Sirius* and *α Gruis*. David Gill.

List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary.

The Lords Commissioners of the Admiralty.
The French Government.
The Netherlands Government.
The Norwegian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Camera Club.
City of London College.
Geological Society of London.
London Mathematical Society.
Meteorological Office.
Physical Society of London.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Photographic Society of Great Britain.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
University College, London.
Belfast Natural History and Philosophical Society.
Cambridge, Adams Memorial Committee.
Cambridge Observatory.
Cambridge Philosophical Society.
Cambridge University Press.
Cardiff, Astronomical Society of Wales.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Edinburgh, Royal Observatory.
Galway, Queen's College.
Kew Observatory.
Leeds Astronomical Society.
Leeds Philosophical and Literary Society.
Liverpool Literary and Philosophical Society.
Liverpool Observatory.
Manchester Literary and Philosophical Society.

Oxford, University Observatory.
Rugby School Natural History Society.
Stonyhurst College Observatory.
Truro, Royal Institution of Cornwall.
Adelaide Observatory.
Amsterdam, Royal Academy of Sciences.
Arcetri, Royal Observatory.
Athens, National Observatory.
Australasian Association for the Advancement of Science.
Baltimore, Johns Hopkins University.
Batavia, Magnetical and Meteorological Observatory.
Batavia, Royal Society of Natural History.
Belgium, Royal Observatory.
Berlin, International Geodetic Association.
Berlin, Physical Society.
Berlin, Royal Astronomical Institute of Computation.
Berlin, Royal Observatory.
Berlin, Royal Prussian Academy of Sciences.
Berne University.
Bombay Branch of the Royal Asiatic Society.
Bombay Government Observatory.
Bonn, Royal Observatory.
Bordeaux Observatory.
Boston, American Academy of Arts and Sciences.
Brisbane, Royal Geographical Society of Australasia.
Brussels, Royal Academy of Sciences.
Buda-Pesth, Hungarian Academy of Sciences.
Buda-Pesth, Royal Hungarian Institute for Meteorology and Terrestrial Magnetism.
Buenos Aires, Argentine Meteorological Office.
Calcutta, Asiatic Society of Bengal.
Calcutta, Surveyor-General of India.
Canada, Geological Survey.
Cape of Good Hope, Royal Observatory.
Cape Town, South African Philosophical Society.
Catania Observatory.
Cherbourg, National Society of Sciences.
Chicago, Academy of Sciences.
Copenhagen, Royal Danish Academy of Sciences.
Cordoba, Argentine National Observatory.
Cracow, Academy of Sciences.
Delft, Polytechnic School.
Dijon, Academy of Sciences.
Geneva Observatory.
Geneva, Society of Physics and Natural History.
Göttingen, Royal Society of Sciences.
Halifax, Nova Scotian Institute of Sciences.
Halle, Imperial Leopold-Caroline Academy.
Harvard College Astronomical Observatory.
Helsingfors, Geographical Society of Finland.

Helsingfors, Society of Sciences of Finland.
Hong Kong Observatory.
International Committee of Weights and Measures.
Italian Meteorological Society.
Kasan, Imperial University.
Leipzig, Astronomical Society.
Leipzig, Prince Jablonowski Society.
Leipzig, Royal Society of Sciences of Saxony.
Lick Observatory.
Madison, University of Wisconsin.
Madras, Government Observatory.
Madrid, Royal Academy of Sciences.
Manila Observatory.
Mauritius, Royal Alfred Observatory.
Melbourne, Government Observatory.
Melbourne, Royal Society of Victoria.
Meudon Observatory.
Montpellier, Academy of Sciences.
Moscow, Imperial Society of Naturalists.
Munich, Royal Bavarian Academy of Sciences.
Naples, Academy of Physical and Mathematical Sciences.
Natal Observatory.
Nice Observatory.
O-Gyalla, Central Meteorological and Magnetical Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, General Depôt of Marine.
Paris, Permanent Astrographic Committee.
Paris, Mathematical Society of France.
Paris Observatory.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Pola, Meteorological and Magnetical Observatory.
Potsdam, Royal Geodetic Institute.
Prague, Imperial Observatory.
Pulkowa Observatory.
Rio de Janeiro Observatory.
Rome, Central Meteorological Office.
Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy *dei Lincei.*
Rome, Royal Academy *dei Lincei.*
St. Petersburg, Astronomical Society of Russia.
St. Petersburg, Astronomical Observatory of the Imperial University.
St. Petersburg, Imperial Academy of Sciences.
San Fernando Observatory.
San Francisco, Astronomical Society of the Pacific.
Stockholm Observatory.

Stockholm, Royal Swedish Academy of Sciences.
Strassburg, Imperial University Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya, National Astronomical Observatory.
Tiflis, Physical Observatory.
Toronto, Astronomical and Physical Society.
Toronto, Canadian Institute.
Toronto, Royal Society of Canada.
Toulouse, Geographical Society.
Turin, Royal Academy of Sciences.
Upsal Observatory.
Upsal, Royal Society of Sciences.
Vienna, Austrian Geodetic Bureau.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Ministry of Marine.
Vizagapatam, G. V. Juggarow Observatory.
Washburn Observatory of the University of Wisconsin.
Washington, Office of the American Ephemeris.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Coast and Geodetic Survey.
Yale University Astronomical Observatory.
Zurich, Geodetic Commission of Switzerland.
Zurich, Natural History Society.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editors of the "Astronomical Journal."
Editor of "Astronomische Mittheilungen."
Editor of the "Astronomische Nachrichten."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
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ADDRESS

Delivered by the President, Sir Robert S. Ball, LL.D., F.R.S., on presenting the Gold Medal to Mr. W. F. Denning.

It is the duty of your President at this annual meeting of our Society to address you on a very important subject. I allude of course to the award of the Gold Medal which is annually conferred by the Royal Astronomical Society on some astronomer who has rendered signal service to our science. The discharge of that duty is perhaps the most responsible official act which devolves on the occupant of this chair, during his tenure of the distinguished position of President. I am to set forth the grounds upon which on the present occasion the medal has been awarded by your Council to our distinguished Fellow Mr. W. F. Denning.

At an early age Mr. Denning manifested that taste for the study of Natural Science, which by diligent cultivation has in due course led him to make those discoveries which we now propose to honour by the highest means in our power. In his boyhood, it was natural history in the study of field life to which, like many another illustrious man of science, he was specially attracted. But the 'stars which in Earth's firmament do shine,' though the stars of his first love, were not the stars by which he was destined to advance to fame. In 1865 Mr. Denning, being then a youth of 17, directed his attention to astronomy, and in the following year he became the possessor of a telescope of three inches aperture.

Stimulated by the views of the celestial glories offered him by this little instrument, Mr. Denning became, as does always the zealous observer, eager to increase the optical powers at his disposal. For a short time he pursued his observations with a 4½-inch reflector, but this again only quickened his desire to have still greater aperture. His wishes in this direction were at last gratified, when in 1870 he purchased a 10¼-inch reflector by Browning. It is with this instrument that Mr. Denning's telescopic work, which we are presently to notice, has been chiefly done.

The contributions of Mr. Denning to astronomy may be conveniently ranged under three heads :—

1. *Discovery of Comets.*
2. *Observation of Planetary Phenomena.*
3. *Researches on Luminous Meteors.*

It will be convenient for me to describe his work in these three different departments, taking them in the order just given.

The first and second departments must, however, be treated with comparative brevity, for in making their award your Council have laid special stress on Mr. Denning's Researches on Luminous Meteors.

1. *Comets.*

Each year usually brings the announcement of certain new comets. The discovery of such objects falls to those observers who patiently scan the heavens evening after evening, and morning after morning, with the particular object of detecting these shy visitors to our skies. Mr. Denning has been one of those who have engaged in this work, and his success has been noteworthy. The following list gives the designations of five comets which have been discovered by our medallist.

Comet 1881 V. Period 8·68 years.
" 1890 VI.
" 1891 I.
" 1892 II.
" 1894 I. Period 7·3 years.

I think it will materially enhance our appreciation of Mr. Denning's perseverance and skill if we note the unique position which he occupies among astronomers in England, so far as the discovery of comets is concerned. Since the days of Caroline Herschel, the only comets, beside those just mentioned, which have been discovered in this country have been those which were detected by Hind and the remarkable object which was found by Mr. Holmes.

While searching the skies for comets Mr. Denning has not unfrequently discovered nebulæ which had escaped the attention of previous observers. No fewer than twenty-one nebulæ have thus been added by Mr. Denning to the lists of those already known. Most of these new objects lie in the vicinity of the North Pole.

2. *Planetary Observations.*

A striking characteristic of Mr. Denning's work is the methodical accuracy with which he has carried through whatever astronomical research he had in hand. Mr. Denning never spared

himself any pains in the efforts necessary to give his work the inestimable charms of thoroughness and precision. This may well be illustrated by his work on *Jupiter*. It is well-known that this very difficult object not only demands instruments of much optical perfection, but also calls for the exercise of the highest qualities which constitute a consummate astronomical observer. Mr. Denning made admirable sketches of the planet, in which he represented a remarkable amount of detail with a skilful pencil. But he was not content with artistic work merely, however valuable such work may be; he patiently watched the revolutions of a large number of spots on *Jupiter*, and determined as accurately as possible their times of transit over the central meridian of the planet. By such observations he ascertained the periods of rotation of a large number of particularly well marked spots. Thus he illustrated the instructive fact that individual spots are animated by large proper motions on the surface of the planet. The famous red spot so well known to every astronomer has been in particular most diligently followed by Mr. Denning. He has demonstrated the remarkable circumstance that the period in which it returns to the central meridian of the planet varies from year to year. The results at which he has thus arrived are in close accordance with the observations of other accomplished astronomers.

3. *Researches on Luminous Meteors.*

The great work of Mr. Denning's scientific career, and that which has been mainly instrumental in deciding your Council to confer on him the distinction of the Gold Medal, has been devoted to the very important subject of luminous meteors. The labours of Mr. Denning have been so extensive (and they cover nearly every branch of the subject of meteorological astronomy), that it would be difficult—indeed, I may say it would be impossible—to render any adequate account of it within the limits of an address; I am therefore obliged to restrict myself to those more salient points which have specially influenced the decision of your Council.

The papers on luminous meteors communicated to the Royal Astronomical Society by Mr. Denning, and printed in the *Monthly Notices*, number altogether forty-two. In bulk they would, if collected together, constitute two-thirds of an ordinary annual volume in that form of the Society's publication. These papers are illustrated with graphic and instructive figures much more copiously than has usually been the custom in communications of this class.

A considerable number of these memoirs contain valuable lists of meteoric radiants, derived either exclusively from Mr. Denning's own work at Bristol or from his own observations in connection with the work of other astronomers in the same field.

Mr. Denning's first published list of radiants appeared in 1876. It contains the determinations of twenty-seven radiant points derived from his own observations of nearly nine hundred meteor tracks which he had himself mapped at Bristol between 1871–6. In this early list the periods of the recurrence of the showers are occasionally indicated by single days or short periods, but usually the month of recurrence is alone given. The list contains careful determinations of the radiant points of the chief annual showers, such as *Quarantids* in 1873, the *Lyrids* in 1873 and 1874, the *Perseids* in 1871 and 1874, the *Orionids* in 1874, and the *Andromedids* in 1872. It is interesting to note that to all but four of the radiants in the list corresponding showers were found in Mr. Greg's first general star shower catalogue. This was published in comparison with Dr. Heis' and other well-known contemporary radiant-lists, in the British Association volume of *Reports* for the year 1874. The four radiants which Mr. Denning did not find corroborated in that general catalogue, are all, it ought to be observed, marked as doubtful ones in this early list.

The latest list of radiants which has been issued by Mr. Denning, and the longest paper that he has as yet communicated to the *Monthly Notices*, was published in 1890. This important work gives remarkable evidence of the diligence of our medallist. It contains a list of 918 radiant points, deduced from the observations of no fewer than 9177 meteors, mapped at Bristol between the years 1873 and 1889. This list, it should be remarked, includes repeated observations of the same radiants. This is the case, not only with regard to the chief showers, but also with regard to various minor showers whose yearly dates of recurrence cannot in the present state of our knowledge be assigned with any certainty.

Though many of these showers are but sparsely characterised by meteors—or, to use the more technical expression, are showers of great tenuity, they have not escaped the persistent scrutiny of Mr. Denning. In such cases the dates, are generally assigned to single days when the meteors have apparently maximum abundance. A column of supplementary dates, which seldom range over more than a week, has been added. It will thus be seen that this catalogue presents an extensive series, not so much of averaged results, as of exact and valuable individual determinations.

In other papers by Mr. Denning mean results have been given which may be regarded as summarising the present state of our knowledge with regard to many important showers. For the chief meteoric showers a list of this kind was published in 1888. In it will be found mean positions for 1880 derived from fifteen years of observations of the radiant points of the nine chief yearly showers. These contain the seven well-known periodic swarms of January, April, August, October, November (two showers), and December, adding to these the striking and

very regularly visible displays of May 6 and July 28. A very useful list of 35 radiants is given by Mr. Denning in the *Admiralty Manual of Scientific Inquiry* (5th edition), 1886.

As an illustration of the perseverance and skill which has been shown by Mr. Denning in the determination of the positions of the radiants, I may mention the following circumstances with respect to the radiants of the *Lyrids*. In 1867 the April meteors were shown by Galle and Weiss to present a similarity of orbit to that of Comet I, 1861. Weiss gave the cometary radiant as R.A. 270°·4, Decl. +33°·5, while Professor Herschel afterwards computed it as R.A. 270°·5 and Decl. +32°. The meteoric radiant was at R.A. 278°·2, Decl. +34°·5 (Galle and Karlinski), at R.A. 277°·5, Decl. +34°·5 (Greg and Herschel), at R.A. 277°, Decl. +38° (Heis), and at R.A. 267°, Decl. +35° (Serpieri). These positions gave a mean radiant a few degrees N.E. of the calculated radiant of the comet, and this discrepancy rendered the supposed identity of the meteors with the comet somewhat questionable. In 1873 and 1874 Mr. Denning watched the April meteors, but his observations were not very complete at that period, and he found the radiant at R.A. 274°, Decl. +37°. In 1878 and later years, having gained the experience necessary in critical meteoric work, he redetermined the radiant and found it practically identical with that computed from the cometary orbit. His positions were:—

	R.A.	Decl.	
1878 April 20–21 … …	272°	+32°	10 meteors
1879 April 20 … …	272°	+33°	8 "
1884 April 19 … …	269°	+33°	17 "
1885 April 19–20 … …	271°	+33°	24 "
1887 April 19–20 … …	270°	+32°	11 "
1893 April 20–21 … …	272½°	+33½°	15 "

The detailed accounts of Mr. Denning's observations of many special meteor showers constitute several of his most valuable papers. The first paper that he ever communicated to the Royal Astronomical Society related to the famous shower in 1872. I dare say many of those present will recollect, as I do myself, that beautiful display of the *Andromedids*. It may be noted, as a matter of interest on the present occasion, that this memorable night may also be said to coincide with the commencement of Mr. Denning's career in connection with our Society. But he has put it on record that he commenced to observe meteors some years earlier, on the occasion of the ever memorable display of the *Leonids* in 1866.

In this earlier paper Mr. Denning tells us, among other interesting matters, how he made his observations of the *Andromedids* in 1872. Watching with one companion between 6 and 6.30 that evening, they enumerated from seventy-five to eighty *Andromedids*, and only one unconformable meteor was noticed. Of

the meteors they saw about ten or fifteen were at least of the first magnitude, and as the rest were bright enough to be seen in the hazy sky, they must have been of about the second magnitude. From the many tracks that were mapped down, as well as from some stationary meteors which were also noticed, the radiant point was found very well defined, and was located at R.A. 29°, Decl. +46°, about 4° north of γ *Andromedæ*.

With this early work of Mr. Denning's it is interesting to compare the observations that he made of the same shower when in 1885 it had completed two more revolutions. This he describes in the paper communicated that year to the *Monthly Notices*. If I give here an abstract of his observations, it is because I think it is no exaggeration to regard them as a model of the way in which the phenomena of luminous meteors should be watched for, and an instructive lesson as to the points to be specially recorded.

He commenced to watch for the great display of *Andromedids* in partly clouded sky on 1885 November 26. In a clear quarter of an hour, from 8.30 p.m. and later in a few periods, twenty-one and forty-two meteors respectively were counted by Mr. Denning and another observer. It is estimated that they were thus arriving at the rate of about 130 per hour. Of those seen nineteen and forty-one were *Andromedids*, and their radiant region, which was some degrees wide, appeared to have a centre about R.A. 26°, Decl. +44°. From midnight onwards the sky was overcast.

On the following night, 1885 November 27, a rich star shower was observed from twilight until 6.40 p.m., when clouds and rain came on. The number would probably have reached 5000 per hour had the sky been perfectly clear, for 222 were counted through the haze in the last and clearest five minutes, showing themselves in intermitting pulses or volleys of five to ten or more at a time. The radiation was decidedly diffuse, proceeding in a loosely disjointed way from an area fully 7° in diameter about a centre at R.A. 24°, Decl. +44° between γ and ξ *Andromedæ*. Several of the meteors seen on the 26th, and many on the 27th, were as bright as *Jupiter*, indeed some of those on the 27th were brighter than *Venus*. They seemed to be composed of loose materials crumbling away in their flight to spark dust ere they vanished.

A chart of forty-nine *Andromedids* and a list of twenty bright ones are given as observed on the evenings of November 26 and 27, showing the mean radiant-point at R.A. 25°, Decl. +44°.

Forty-five more *Andromedids*, half of them of rather smaller magnitudes, were noted in about four hours—on the evening of November 28, and a chart of their tracks showing a radiant-point at R.A. 22°, Decl. +43½° was also given.

Ten meteors of the same shower were seen on November 30 in 4½ hours, and these were sufficient to give a radiant at R.A. 21°, Decl. +42½°; but on December 1, 4, and 7, no further symptoms

of the shower were traceable. In its whole duration of fully five days (it lasted very possibly one or two more days, for clouds prevailed at its commencement), the radiant-point was thus observed to recede about five degrees in right ascension.

The rather bright shower from *Andromeda* of forty per hour, which was seen on 1872 November 24, 7.30 to 12 p.m., at New-haven, Conn., and more faintly on the following night, was certainly not continuous with the grand display of November 27 in the same year. The nights of November 25 and 26 were noted by Mr. Denning, at Bristol, as unsurpassed in November for paucity of meteors.

Another very interesting shower admirably studied by Mr. Denning was that from 1897 April 29 to May 6. Of all the shooting stars appearing through the year, there are none more striking for their long, bright, streak-leaving courses than those which from April 29 to May 6 may be seen after midnight proceeding from that radiant-point at the east horizon, first defined by Colonel Tupman in 1869–70 near α and η *Aquarii*. The orbit of Halley's comet approaches the earth's orbit near the position occupied by the Earth on May 4. The distance is about five and a half million miles on the inner side of the earth's track. The magnitude and brightness of that comet's tail projecting outwards from the Sun suggests the possibility of its connection with this shower. Fragments accompanying the comet would have an apparent radiant-point nearly at η *Aquarii*, but this is 12° E on the equator from the radiant found for the meteor shower by Colonel Tupman.

A trial was made by Mr. Denning to re-determine this star-shower's date and radiant-point exactly, by projecting 229 tracks in April and May from the Italian Meteor Association's Catalogue of about 7600 meteor paths observed in 1868–70. A resulting place at R.A. 335°, Decl. −9° was obtained for the radiant-point. This is considerably southward and eastward from Colonel Tupman's position at R.A. 326°, Decl. $-2\frac{1}{2}°$, but yet does not agree very well with the computed radiant R.A. 337°, Decl. ±0° on May 4, of a stream of meteor particles from Halley's comet.

The late hour of the radiant's rising, between 1^h and 2^h a.m., makes a good view of this splendid shower not easy to obtain.

Its centre had been noted by Mr. Corder from observations made in 1876–79, at R A. 334°, Decl.—5°. But the difficult task of carefully re-observing this shower's radiant-centre remained for Mr. Denning to accomplish, and he watched the sky on a succession of clear, moonless nights in April–May 1886, for 27 hours for this purpose, mapping in all 117 meteors in a time of unusual scarcity of shooting-stars, with a perseverance and success perhaps never surpassed in meteor-observations. From nine very accordant tracks of the beautifully long-pathed Aquarid meteors seen between April 30 and May 6, most abundantly on the latter date, and from three others which only

deviated a few degrees from the position, the centre of the shower was found, with only slight diffuseness, to be at R.A. 337°, Decl. $-2\frac{1}{2}°$; all doubt of its agreement in place and date with the time and radiant-point of a shower connected closely in some way with the orbit of Halley's comet being thus clearly shown to be unfounded.

In the *Monthly Notices* for 1894 June, Mr. Denning sums up his extensive experience on the questions of the general directions of great fireballs, and of the brighter shooting stars as compared with those of ordinary shooting stars. He tells us that the striking objects commonly diverge from radiant-points at places in the western or anti-apical half of the sky, quite remote from the radiant-points of contemporaneous meteor showers. This noteworthy result is arrived at not only from most of Mr. Denning's own determinations of the real paths of such meteors, but from a numerous collection of published determinations of these paths which he has brought together for comparison with his own results.

This singularity of direction, for so it at first appeared, seems now to be a regular feature of the usual movements of fireballs. That a great fireball, leisurely streaming across the sky, should come from a westerly direction, is quite a normal circumstance; a movement in this direction is, however, rarely seen in the case of ordinary shooting stars.

Although a connection between a fireball and some weak contemporaneous shower may now and then be perhaps traced, yet many fireballs seem to be so isolated that Mr. Denning has been led to suspect that they "must either be merely single sporadic bodies, or else the survivors from some meteor group nearly exhausted by the waste of its material during many past ages."

In a weighty concluding paragraph touching the question of the similarity or the diversity of origin of meteorites, fireballs, and shooting stars, Mr. Denning quotes the late Professor H. A. Newton's striking conclusion from his study of observed paths of meteorites. It appears that, out of 116 stone falls investigated by the diligent American astronomer, 109 must have been overtaking the Earth, and only seven seem to have met the Earth. He infers from this that nearly all the stones in the Solar System move in direct orbits.

As an illustration of the thoroughness of the work of Mr. Denning in the interesting problem of the determination of the path of a fireball, we may consider the remarkable object which appeared at ten o'clock on the evening of 1894 January 25. This was a large detonating fireball which, in a generally clouded sky, is stated to have illuminated the north-western parts of England as brightly as the full Moon is able to do. It disappeared at the end of a long obliquely-descending course from N.W. to S.E. at a height of sixteen miles over a point three or four miles east from Tewkesbury. At Malvern and Worcester,

on either side of the end of its track, as well as at other places, a violent explosion was heard which resembled a clap of thunder. The report reached Malvern after an interval of about three minutes, corresponding to a distance of 37 miles. Various other incidents of the explosion have been also collected from different sources.

Mr. Denning carefully sifted more than forty accounts of the occurrence collected from different English and Welsh localities. Those which were found to be available for the actual determination of the path of the fireball were the observations near Lancaster by Mr. Clapham, near Birmingham by Messrs. Packer and W. H. Wood, at Sunderland by Mr. Backhouse, and by Mr. Denning himself at Bristol. The visible extent of the meteor's real path thus obtained was found to be about 160 miles, which was traversed in about 9 seconds. Its course began 89 miles high over the Irish Sea, 24 miles N.N.E. from Amlwch, in Anglesey, and passing at heights of 45 and 22 miles nearly over Shrewsbury and Worcester to the above-named terminal point.

The direction of flight was from near ϵ *Cephei*, a place not known previously as a radiant-point of shooting stars so late in winter, although a centre near this was found on 1886 January 4–8 by Mr. Denning, and though in summer and in autumn months radiant-points in the same quarter are numerous. This point is, in fact, one of those enumerated in the list of 45 stationary radiant-points at the end of Mr. Denning's list of 918 radiant-points. It is noted as having been seen with very prolonged duration from June to December in the fine summer months of 1887. The parabolic meteor speed corresponding to this deduced radiant-point is $13\frac{3}{4}$ miles per second, while the observed velocity was 18 miles per second.

The most important contributions which Mr. Denning has made to the general problems connected with luminous meteors are undoubtedly connected with the long duration of meteoric radiants. The fact of long persistency of radiant-points, and of close assemblages about the points, of groups or compact families of simultaneous or successive meteor streams is as old as Heis' first essays in meteor showers. It is, however, to Mr. Denning's inquiries that we are indebted for our knowledge of this subject. In his important paper of 1884 December, Mr. Denning writes: "The fact of stationary radiants exhibiting visible activity during several months is a phenomenon so unaccountable and so utterly opposed to the approved theories as to the orbits of shooting stars that it must receive a most crucial examination before it can be accepted."

The long-continued labours of Mr. Denning on this important subject have demonstrated the existence of these enduring radiants. The theoretical difficulties connected with the subject may be still not altogether removed, but we can hardly refuse assent to Mr. Denning's words when he says: "It must be conceived that a well-attested fact of observation, however hard to

reconcile with known theories, ought on no account to be disregarded on account of its nonconformity."

It is, of course, known that the *Perseids* of the August meteor-shower are found, not only on the special nights with which the swarm is chiefly associated; they are also displayed on many preceding and following nights. Mr. Denning has traced meteors of this group for the twenty-six nights from July 25 to August 19, and their radiant advanced in that interval over a distance of forty degrees. In one of those admirable diagrams by which the interest of Mr. Denning's papers is so greatly increased, he gives a curve of the ordinary number of *Perseids*, rising from one on July 25 to a maximum of fifty-seven on August 10, and then declining to one on August 19. In his paper of 1890 Mr. Denning shows that the range of the *Perseids* is even wider still. I cite this case of the *Perseids*, because the gradual shift of the radiants, as days and weeks pass by, is of course no more than should be expected from the change of the place of the Earth in its orbit. The extraordinary fact is that in the case of certain other showers, which are visible for weeks or months, the radiant undergoes no appreciable change in position.

The six showers that Mr. Denning specially selects for discussion in his memorable paper of 1884, are as follows; we direct special attention to these results, because they may be regarded as the authoritative announcement of the important discovery under consideration.

	Radiant. R.A.	Radiant. Decl.	Apparent Duration.	Shower.	Positions Averaged.
I.	30°0	+36°0	July 16–Nov. 14	β Triangulids	23
II.	46·0	+45·6	July 6–Nov. 30	α–β Perseids	31
III.	61·0	+47·7	July 25–Nov. 27	μ Perseids	21
IV.	61·8	+36·8	Aug. 2–Dec. 31	ε Perseids	26
V.	76·2	+32·6	July 23–Dec. 27	ι Aurigids	21
VI.	80·2	+22·9	Aug. 24–Jan. 15	ζ Taurids	25

Taking the second of these showers as an example, we have fifteen determinations of the radiant II., by Mr. Denning himself, extending from July 6 to November 14. The mean of that concordant series of determinations places the radiant at R.A. 46°·1 and Decl. +45°·0.

Then follow sixteen determinations of the radiant by other skilled observers of meteors, Schmidt, Tupman, Schiaparelli and Zezioli, Maggi, Heis, Corder, Sawyer, Greg, and Herschel. Here again we have another series of results extending from August 3 to November 30, placing the mean radiant at R.A. 45°·8, Decl. +46°·2. It is impossible to resist the logic of these facts; whatever may be their explanation, the existence of the enduring radiants must be admitted.

Such a paper as that which I am now referring to must be regarded as a classic which everyone who desires to devote himself to the fascinating subject of meteors would do well to study. It is full of interesting facts and suggestion. We learn that in the catalogues published up to this date there are no fewer than 2100 radiants resulting from the projected paths of upwards of 62,000 meteors; many of these are known duplicate observations of identical streams, and Mr. Denning adds that he does not believe the total number of well defined streams would exceed 350.

Mr. Denning has given in the introduction to his great catalogue of 1890 a very interesting general statement of his methods of work.

"My plan of working may be briefly described as follows:— All the observations were made in the open air, and from the garden adjoining the house. Attention was almost invariably given to the eastern sky. In mild weather I sat in a chair with the back inclined at a suitable angle; but on cold, frosty nights I find it expedient to maintain a standing posture, and sometimes to pace to and fro, always, however, keeping the eye directed towards the firmament in quest of meteors."

"I find it essential to rely on the latter instrument (a perfectly straight wand) as a help and corrective to the eye in ascribing the lines of flight. When a meteor was seen the wand was immediately projected upon its track and the position quickly noted and reproduced on an 18-inch celestial globe. The time, magnitude, appearance, beginning-point and probable radiant were then written down, and other details left to be filled in on the following day, when all the paths were carefully compared and their provisional radiants derived."

Mr. Denning points out that in open country places the mean horary number of meteors is 11·4. The average lengths of the paths of all the meteors he has observed is 10°, and the maximum number of meteors is attained between 2 and 3 a.m., when the rate is nearly double that in the early hour of the evening.

On the important subject of stationary radiants additional information has been acquired during the five years following the important statement of 1884. It has been tested by about 5000 observations made since that time, and the new materials certainly seem to corroborate the conclusion already arrived at. Mr. Denning here again refers to the remarkably long enduring shower between α and β *Persei*. He has obtained several fresh determinations of it, and he gives it as one of the best instances of an apparently stationary radiant. The following is the remarkable table referred to:—

Long enduring shower between α and β Persei.

		R.A.	Decl.			R.A.	Decl.
1877	July 20	47°	+45°	1885	Sept. 15	48°	+43°
1884	July 23–25	48	+43	1877	Sept. 15–16	47	+45
1886	Aug. 2–10	48	+43	1886	Sept. 22–30	48	+44
1888	Aug. 5–14	48	+44	1887	Oct. 17–24	47	+44
1877	Aug. 3–16	46	+45	1879	Oct. 20	45	+46
1884	Aug. 19–21	46	+44	1879	Nov. 12–14	48	+43
1879	Aug. 21–23	46	+47	1877–86	Nov. 27–Dec. 8	48	+42
1887	Aug. 30	46	+43	1886–8	Dec. 28–Jan. 11	47	+44
1887	Sept. 12–24	47	+43	1876–87	Feb. 23–Mar. 12	47	+45

Mr. Denning has recently published in the *Observatory* an instructive and opportune series of papers on the expected great showers of *Leonids* in the next few years. This subject is here discussed with that wealth of knowledge and experience which characterises all Mr. Denning's contributions. He commences these papers with the words :

"It may safely be said that in the month of November during the next few years, all astronomers and a large majority of the general public will become meteoric observers, for the phenomena presented will be of an exceptional kind, and of a character to interest everyone."

We all echo these remarks. I think I am justified in adding that much of the recently-awakened interest in the subject has been due to the worthy example Mr. Denning has himself given us. Who among us would not be proud to imitate his single-hearted and enthusiastic devotion to the discovery of truth in this beautiful department of astronomy?

It is a matter of great regret to everyone here assembled that our medallist, whom we so greatly wish to honour, is not now present in person to accept our award. We regret this all the more when we learn that ill health is the cause of his absence. We unite in expressing a hearty wish for his speedy recovery. We assure him not only of our appreciation of his admirable work, but of the high esteem which we personally entertain for him. On your behalf, therefore, I now hand the Gold Medal of the Royal Astronomical Society to our Secretary, to be by him transmitted to Mr. W. F. Denning in recognition of the valuable services to our science which he has rendered, especially in the department of meteoric astronomy.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :

President.

Sir R. S. Ball, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.

Vice-Presidents.

Capt. W. de W. Abney, C.B., R.E., D.C.L., F.R.S.
W. H. M. Christie, Esq., C.B., M.A., F.R.S., Astronomer Royal.
A. A. Common, Esq., LL.D., F.R.S.
J. W. L. Glaisher, Esq., M.A., Sc.D., F.R.S.

Treasurer.

E. B. Knobel, Esq.

Secretaries.

H. F. Newall, Esq., M.A.
H. H. Turner, Esq., M.A., B.Sc., F.R.S., Savilian Professor of Astronomy, Oxford.

Foreign Secretary.

Sir William Huggins, K.C.B., LL.D., D.C.L., F.R.S.

Council.

G. H. Darwin, Esq., M.A., LL.D., F.R.S., Plumian Professor of Astronomy, Cambridge.
A. M. W. Downing, Esq., M.A., D.Sc., F.R.S., Superintendent of the *Nautical Almanac.*
F. W. Dyson, Esq., M.A.
Capt. E. H. Hills, R.E.
Major P. A. MacMahon, R.A., D.Sc., F.R.S.
W. H. Maw, Esq.
Capt. William Noble.
A. A. Rambaut, Esq., D.Sc., Radcliffe Observer.
G. M. Seabroke, Esq.
E. J. Spitta, Esq.
G. Johnstone Stoney, Esq., M.A., D.Sc., F.R.S.
W. G. Thackeray, Esq.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. MARCH 11, 1898. No. 5

SIR R. S. BALL, LL.D., F.R.S., PRESIDENT, in the Chair.

Eric Doolittle, B.Sc., Flower Observatory, University of Pennsylvania, Philadelphia, Pa., U.S.A.;
Rev. Kingsbury Jameson, M.A., Highfield, Hendon; and
Alfred Taylor, Polvellan, Holgate Hill, York,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

George Banaster, The Mythe Villa, Tewkesbury (proposed by the Rev. C. D. P. Davies);
Edward J. Essam, Chemist, Billingborough, Lincolnshire (proposed by the Rev. W. R. Waugh);
The Hon. George Stuart Forbes, I.C.S., Revenue Secretary to the Governor of Madras (proposed by C. Michie Smith); and
The Rev. William Edward Winks, 58 Richmond Road, Cardiff (proposed by Arthur Mee).

One hundred and seven presents were announced as having been received since the last meeting, including, amongst others :—

Nautical Almanac for 1901, presented by the Lords Commissioners of the Admiralty; M. W. Meyer, *Das Weltgebäude*; and W. Peck, the Observer's Atlas of the Heavens; presented by the authors.

Note on Dr. Gill's paper "On the Effect of Chromatic Dispersion of the Atmosphere on the Parallaxes of α Centauri and β Orionis, etc." By Arthur A. Rambaut, M.A., Sc.D., Radcliffe Observer.

In the *Monthly Notices* for 1897 December Dr. Gill publishes a paper under the above title, in which he criticises very adversely some conclusions on the same subject which I communicated to the Society in 1895 January.

Before proceeding to examine his arguments I should like to correct an impression which his paper is likely to convey, and to state that the object of my former communication was, not to criticise Dr. Gill's method of discussing his heliometer measures of *α Centauri*, nor to obtain the most probable value of the parallax of this star, but merely to see how far his observations supported the hypothesis that the effect of a difference in the mean refrangibility of the light of two stars is really sensible in refined astronomical measures, and it is only incidentally that the question of the exact numerical value of the parallax enters at all. Thus on p. 135 of the *Monthly Notices*, vol. lv., in the paper referred to, I say: "I have accordingly examined this series of measures, and the three which follow it in the same Memoir, with a view to establishing the existence of such a difference." Again, on p. 141 I say: "My object at present is, not to improve on the value of the parallax deduced . . . but to examine the effect which atmospheric dispersion may have on such measures." It is only at the very end of the paper, in summing up the results of my investigation, that I refer to the values of the parallax which I arrived at in these terms: "Whatever value may be assigned to the particular solutions which I have found, . . . and whether it be thought that the correction I have introduced accounts fully for the systematic error depending on hour angle which runs through them all, and that the still outstanding quantities should be attributed to the accidental errors inseparable from observations of such delicacy and difficulty . . . I think I have shown at least that in parallax measures a term ought to be introduced into the equations of condition of the form

$$d\beta \tan \zeta \cos (p-q)$$

where results of the highest precision are aimed at"—a conclusion which I still think is justified.

Although, however, in my paper above referred to I did not discuss Dr. Gill's method of solving his equations of condition, it has always seemed to me most unsatisfactory to assume empirical corrections to remove the larger residuals and then, appealing to the smallness of the resulting residuals as a proof of the accuracy of the observations, to compute the probable error of the result by means of these reduced residuals.

This method, while it *may* lead to approximate values of the quantities sought, is sure to give a false impression as to the accuracy of the result.

I did not, however, feel that I was in any way called upon to criticise Dr. Gill's solution, nor to express my opinion as to the admissibility of his methods, and therefore I did not at the time examine the point further.

But now that Dr. Gill has attacked my conclusions and condemned my results, the question assumes quite a different complexion. I have no choice but to take up the gage which he has thrown down, and to point out what I believe to be an error in his mode of treating the observations, and especially in estimating the precision of his results.

It is, I think, a mistake in principle to assume the existence of constant errors unless one is absolutely driven to it. The fact of an error of the same sign affecting a number of observations in a series does not prove it to be constant, and in assuming it to be so we assume not only its magnitude but the law of its operation. It is quite different when we suppose the existence of some effect, such as chromatic dispersion, the law of whose operation can be determined *à priori*, and in which we are only in doubt as to the magnitude of the constant factor. In this case, if we force the value of the constant to suit one group of equations, its unreal character will be revealed by the large discrepancies in other groups where its factor is different.

Thus the fact which Dr. Gill quotes against me—namely, that the omission of the terms π and $d\beta$ in the case of β *Orionis* reduces the probable error—seems to show that there is no sensible effect of dispersion or parallax in this series of measures, but has no application to the case of isolated corrections introduced into groups of equations such as Dr. Gill has used.

But in any case, if we assume the existence of constant but unknown errors, and apply corrections for them, we must not ignore the fact that they are *errors*, and we must therefore include them in computing the probable error of an observation. This Dr. Gill has not done, and the computed probable error of his result is consequently very much underestimated. In his recent paper Dr. Gill argues with regard to these corrections that they represent real quantities, with the implication that if this is the case they need not be taken into account in calculating the probable error. But the irregular errors of observation are just

as *real* as the systematic errors, and until we are assured that the latter are really constant, or until we have established the law of their operation, we must treat them as being subject to the law of frequency of errors, and take them into account in estimating the probable error of the result.

Dr. Gill refers to the seriousness of admitting a chromatic dispersion of the amount I have deduced. It is undoubtedly a serious matter if the refraction constant applicable to two neighbouring stars may differ by one or two-tenths of a second; it can, however, in a case like the present be computed and allowed for; but I cannot see how his alternative suggestion that heliometer measures are affected by unknown errors amounting to several tenths of a second is by any means less disquieting.

Now I am not anxious to establish the exact value of the quantity $d\beta$ at which I arrived, and think it very likely that the other errors affecting these measures led to too large a value; nor do I claim that, if judged by the residuals, my solution is superior to Dr. Gill's. There are unquestionably in this series of observations outstanding errors which cannot be fully accounted for by a chromatic dispersion. But

1. I question the validity of Dr. Gill's method of introducing constant corrections to smooth down the roughness of the observations, unless he takes into account the hypothetical character of these corrections in estimating the probable error of the result.

2. I contend that a comparison of the residuals obtained in a direct solution, such as mine, with the empirically corrected residuals which he finds, is no fair test of the relative value of the two solutions.

3. I maintain that the comparison of the mean of the residuals for each group as deduced by him and by me (which he gives on p. 62) is equally fallacious, and that (if it were not for the unavoidable error in the last figure) his means would, from the nature of his solution, be zero in each case.

4. With regard to his statement on p. 57, that "the introduction of terms which have no real values must tend to increase the resulting probable error," I assert that every additional term introduced with a factor unity or (what amounts to the same thing) which is multiplied by the same factor in each equation in which it occurs, must in the solution by least squares reduce the sum of squares of residuals, and that generally, if not always, such terms will have the effect of reducing the probable error whether the real errors be constant or not.

This last point is, indeed, sufficiently obvious; for if in the solution of a series of equations of the form

$$x + by + cz + n = 0$$

we find any considerable number of the residuals grouping themselves around a mean figure, we can at once subtract this mean from each of them and take it across to the other side of the

equation, where in connection with x it will form a new quantity x_1. Indeed, if this principle of correcting equations is admitted without limitations, one can easily get rid of the residuals altogether. Dr. Gill has assumed four such corrections; if he will allow me eight, I can reduce the residuals so that none of them will exceed $0^R{\cdot}010$; twelve such corrections will reduce them all below $0^R{\cdot}005$; while fifty-six would enable me to satisfy the ninety-five equations exactly to three decimal places.

I do not for a moment mean to imply that a solution of this sort is comparable with Dr. Gill's, where his groups were arranged for him by considerations as to the position of the observer's head with regard to the line joining the stars. I merely intend to point out how misleading an appeal to the smallness of the residuals is in such a solution.

In order to see how a solution of this sort would compare with Dr. Gill's, I have solved the equations in the above form, and obtained the residuals given in the fourth column of Table A under the heading "General Solution." They are broken up into four groups as in Dr. Gill's paper, and present all the appearance of being affected by systematic errors. This appearance is, however, very easy to remove, for, taking the mean of the residuals for each group, and applying it with its sign changed as a correction to each, I find the residuals given in the fifth column. These are very similar in character to those found by Dr. Gill; the mean error is not quite so small as Dr. Gill's, being 0·012 as compared with his 0·011. Will Dr. Gill allow that this solution in which the value of π comes out

$$0''{\cdot}819$$

is superior to that I was led to in my paper of 1895, in which the residuals are very much larger?

Hence it is clear that a mere appeal to the residuals is not a safe criterion of the value of a solution. We must consider how those residuals were obtained.

TABLE A.

Group I.

No.	Weight.	Gill.	General Solution.	General Solution corrected.	Separate Solutions.
		R	R	R	R
22	½	−0·028	−0·007	−0·021	−0·015
23	½	− 19	0	− 14	− 8
24	...	− 22	− 4	− 18	− 12
25	...	− 7	+ 10	− 4	+ 1
26	...	− 16	0	− 14	− 9
27	...	− 15	0	− 14	− 10
30	...	+ 6	+ 18	+ 4	+ 8

No.	Weight.	Gill.	General Solution.	General Solution corrected.	Separate Solutions.
		R	R	R	R
32	...	+0·007	+0·017	+0·003	+0·008
33	...	− 11	0	− 14	− 11
34	...	− 12	− 2	− 16	− 13
35	...	+ 1	+ 11	− 3	+ 1
37	...	+ 4	+ 14	0	+ 2
39	½	+ 2	+ 12	− 2	0
42	...	− 5	+ 5	− 9	− 6
45	...	+ 23	+ 34	+ 20	+ 22
46	...	+ 19	+ 29	+ 15	+ 18
47	...	− 1	+ 11	− 3	− 2
50	...	− 7	+ 5	− 9	− 8
52	...	− 6	+ 6	− 8	− 7
56*a*	...	+ 14	+ 31	+ 17	+ 15
61	...	+ 13	+ 33	+ 19	+ 17
63	...	− 1	+ 19	+ 5	+ 2
64	½	+ 12	+ 32	+ 18	+ 15
88	½	− 6	+ 9	− 5	− 20
91	...	+ 7	+ 24	+ 10	− 8
98	...	+ 13	+ 32	+ 18	− 1
104	...	+ 15	+ 39	+ 25	+ 4

Group II.

No.	Weight.	Gill.	General Solution.	General Solution corrected.	Separate Solutions.
31	...	−0·007	−0·014	−0·012	−0·004
36	...	− 8	− 16	− 14	− 4
38	...	+ 9	+ 1	+ 3	+ 13
40	...	− 11	− 19	− 17	− 6
43	...	+ 3	− 10	− 8	+ 2
54	...	+ 5	+ 1	+ 3	+ 4
55	½	+ 14	+ 11	+ 13	+ 13
59	...	− 1	− 1	+ 1	− 8
60	...	+ 14	+ 15	+ 17	+ 6
90	...	+ 3	+ 2	+ 4	+ 7
95	...	− 5	− 5	− 3	− 4
97	½	− 52	− 51	− 49	− 51
101	...	+ 14	+ 18	+ 20	+ 9
103	...	+ 13	+ 19	+ 21	+ 7

Group III.

No.	Weight.	Gill.	General Solution.	General Solution corrected.	Separate Solutions.
		R	R	R	R
1	...	+0·016	−0·002	+0·013	+0·010
2	...	+ 5	− 12	+ 3	− 1
3	...	− 12	− 29	− 14	− 18
4	...	+ 4	− 13	+ 2	− 2
5	...	0	− 16	− 1	− 5
6	...	− 4	− 20	− 5	− 10
7	...	+ 10	− 5	+ 10	+ 5
9	...	− 2	− 13	+ 2	− 6
10	½	+ 8	− 3	+ 12	+ 5
11	...	+ 9	− 2	+ 13	+ 6
12	...	+ 9	− 1	+ 14	+ 6
13	...	+ 19	+ 9	+ 24	+ 16
14	...	− 16	− 27	− 12	− 20
44	...	+ 13	− 15	0	+ 9
49	...	+ 18	− 9	+ 6	+ 15
51	...	0	− 27	− 12	− 3
53	...	+ 2	− 25	− 10	− 2
58	...	+ 13	− 8	+ 7	+ 12
62	...	− 15	− 36	− 21	− 17
67	...	+ 5	− 9	+ 6	+ 6
68	...	− 6	− 21	− 6	− 5
70	...	+ 16	+ 3	+ 18	+ 18
71	...	− 2	− 15	0	− 1
73	½	+ 4	− 7	+ 8	+ 6
74	½	− 35	− 43	− 28	− 31
76	½	+ 4	− 3	+ 12	+ 8
78	½	+ 2	− 4	+ 11	+ 6
79	...	+ 2	− 3	+ 12	+ 7
80	...	− 3	− 9	+ 6	+ 1
81	½	− 22	− 28	− 13	− 18
82	...	+ 4	− 1	+ 14	+ 9
83	...	− 14	− 19	− 4	− 9
84	...	+ 2	− 3	+ 12	+ 7
92	...	− 13	− 35	− 20	− 8
93	½	− 32	− 53	− 38	− 28
94	...	+ 3	− 18	− 3	+ 8

No.	Weight.	Gill. R	General Solution. R	General Solution corrected. R	Separate Solutions. R
96	½	−0·008	−0·028	−0·013	−0·003
99	...	− 4	− 23	− 8	+ 2
100	...	− 2	− 20	− 5	+ 4
102	...	− 25	− 41	− 26	− 15
105	...	+ 9	− 6	+ 9	+ 16

Group IV.

No.	Weight.	Gill.	General Solution.	General Solution corrected.	Separate Solutions.
17	...	+0·014	+0·033	+0·015	+0·020
18	...	+ 9	+ 28	+ 10	+ 15
19	...	− 15	+ 4	− 14	− 9
20	...	− 38	− 19	− 37	− 32
21	...	+ 3	+ 21	+ 3	+ 8
56	...	− 2	+ 6	− 12	− 7
57	...	+ 20	+ 28	+ 10	+ 15
69	...	− 7	+ 10	− 8	− 10
72	...	− 11	+ 7	− 11	− 15
75	½	+ 25	+ 48	+ 30	+ 22
85	½	− 8	+ 18	0	− 12
86	...	− 23	+ 3	− 15	− 27
87	...	+ 39	+ 64	+ 46	+ 34

But though it is thus obvious that a solution very closely resembling Dr. Gill's, as far as the residuals are concerned, may be obtained by carrying the mean value of a group of residuals from one side of the equation to the other, I have yet to prove that this is practically what Dr. Gill has done, and that a solution by least squares with several x's will necessarily amount to this process.

The equations of condition are of the form

$$x + by + cz + n = 0,$$

where x is a correction to the assumed difference of the mean distances between *a Centauri* and the two comparison stars; y is the change in this depending on the time; while z is the effect of parallax. Dr. Gill has introduced a fourth quantity y' depending on the square of the time due to the orbital motion of *a Centauri* as a double star, but its influence is found to be practically insensible in any of the solutions, and as it does not affect the question at issue between us, I have omitted it for the sake of simplicity.

Excepting chromatic dispersion, these are the only effects which we have any *à priori* reasons for considering. If we solve these equations by the method of least squares we get the residuals in

the fourth column of the table which are found to arrange themselves more or less approximately in the four groups which Dr. Gill has selected. If we denote the various quantities by pairs of subscript numbers, the first applying to the group and the second to the position of the equation in the group, we have the following equations of condition and residuals:

$$\left.\begin{array}{c} x+b_{11}y+c_{11}z+n_{11}=v_{11} \\ x+b_{12}y+c_{12}z+n_{12}=v_{12} \\ \text{\&c., \&c.} \end{array}\right\}\text{Group I.}$$

$$\left.\begin{array}{c} x+b_{21}y+c_{21}z+n_{21}=v_{21} \\ x+b_{22}y+c_{22}z+n_{22}=v_{22} \\ \text{\&c., \&c.} \end{array}\right\}\text{Group II.}$$

with similar expressions for the equations of Groups III. and IV.

Now, if we subtract the quantity a_1 from both sides of each equation of Group I.; a_2 from both sides of each equation of Group II., and so for the other groups, and if we denote $x-a_1$ by x_1, $x-a_2$ by x_2, $x-a_3$ by x_3, and $x-a_4$ by x_4, we shall have

$$\left.\begin{array}{c} x_1+b_{11}y+c_{11}z+n_{11}=v_{11}-a_1=V_{11}, \text{ say} \\ x_1+b_{12}y+c_{12}z+n_{12}=v_{12}-a_1=V_{12} \quad ,, \\ \text{\&c., \&c.} \end{array}\right\}\text{Group I.}$$

$$\left.\begin{array}{c} x_2+b_{21}y+c_{21}z+n_{21}=v_{21}-a_2=V_{21}, \text{ say} \\ x_2+b_{22}y+c_{22}z+n_{22}=v_{22}-a_2=V_{22} \quad ,, \\ \text{\&c., \&c.} \end{array}\right\}\text{Group II.}$$

and so on.

Solving these, by the method of least squares, for x_1, x_2, x_3, x_4, y, and z, we have

$$U=V_{11}^2+V_{12}^2+V_{13}^2+\text{\&c.}+V_{21}^2+V_{22}^2+\text{\&c.}+V_{31}^2+\text{\&c.}+\text{\&c.}=\text{a minimum.}$$

Hence the differential coefficient of this expression with regard to each of the quantities x_1, x_2, x_3, x_4, y and z vanishes. But since

$$\frac{dV_{11}}{dx_1}=\frac{dV_{12}}{dx_1}=\frac{dV_{13}}{dx_1}=\text{\&c.}=1, \quad \frac{dV_{21}}{dx_1}=\frac{dV_{22}}{dx_1}=\frac{dV_{31}}{dx_1}=\text{\&c.}=0$$

we have

$$\left.\begin{array}{l} \dfrac{dU}{dx_1}=V_{11}+V_{12}+V_{13}+\text{\&c.}+V_{1n_1}=0 \\ \dfrac{dU}{dx_2}=V_{21}+V_{22}+V_{23}+\text{\&c.}+V_{2n_2}=0 \\ \dfrac{dU}{dx_3}=V_{31}+V_{32}+V_{33}+\text{\&c.}+V_{3n_3}=0 \\ \text{and} \\ \dfrac{dU}{dx_4}=V_{41}+V_{42}+V_{43}+\text{\&c.}+V_{4n_4}=0 \end{array}\right\} \quad \ldots\ldots \quad (a)$$

Hence the sum of the residuals in each group (and, therefore, the mean) vanishes, and thus Dr. Gill's argument founded on a comparison of the means of the residuals in each group is *of absolutely no value whatever*, his solution being artificially constructed to fulfil the condition that these means should each be zero.

Next we find from the equations (a) that

$$a_1 = \frac{\Sigma v_1}{n_1},\quad a_2 = \frac{\Sigma v_2}{n_2},\quad a_3 = \frac{\Sigma v_3}{n_3} \text{ and } a_4 = \frac{\Sigma v_4}{n_4}.$$

And we have

$$U = \Sigma\,(v_1 - a_1)^2 + \Sigma\,(v_2 - a_2)^2 + \Sigma\,(v_3 - a_3)^2 + \Sigma\,(v_4 - a_4)^2 = \Sigma(V^2).$$

With the above values of a_1, a_2, a_3 and a_4 this becomes

$$\Sigma V^2 = \Sigma v^2 - n_1a_1^2 - n_2a_2^2 - n_3a_3^2 - n_4a_4^2.$$

Since n_1, n_2, n_3, and n_4 are positive integers, being the number of observations in each group, it follows that ΣV^2 is necessarily less than Σv^2, and that each additional empirical correction, such as a_1, will have the effect of still further reducing the sum of the squares of the residuals.

Suppose that, in general, there are r unknown quantities, and that we divide the equations into s groups, introducing s constant corrections, we shall have s quantities instead of x, so that the total number of our unknowns will be $r+s-1=R$. Thus the error of mean square, or mean error, computed from the final residuals is $\sqrt{\frac{\Sigma(V^2)}{N-R}}$, N being the total number of equations. If this is to be less than the mean error computed from the unreduced residuals, then we must have

$$\frac{\Sigma(v^2)}{N-r} - \frac{\Sigma(V^2)}{N-R}$$

a positive quantity.

But this is equal to

$$\frac{\Sigma(v^2)}{N-r} - \frac{\Sigma(v^2) - n_1a_1^2 - n_2a_2^2 - \&c.}{N-r-s+1}$$

or

$$\frac{s-1}{N-r-s+1}\left\{\frac{n_1a_1^2 + n_2a_2^2 + \&c.}{s-1} - \frac{\Sigma(v^2)}{N-r}\right\}$$

In order that this should be positive we must have

$$\frac{n_1a_1^2 + n_2a_2^2 + \ldots}{s-1} \text{ greater than } \frac{\Sigma(v^2)}{N-r}$$

or, extracting the square root of each and multiplying by $K(=0{\cdot}6745)$, we must have

$$K\sqrt{\frac{n_1a_1^2 + n_2a_2^2 + \ldots}{s-1}} \text{ greater than } K\sqrt{\frac{\Sigma(v^2)}{N-r}} \quad \ldots\ldots (b)$$

If the final value of x is deduced from the mean of the s separate values, weighting them in proportion to the number of observations on which each depends, these weights are $\frac{s}{N} n_1$, $\frac{s}{N} n_2$, $\frac{s}{N} n_3$, $\frac{s}{N} n_4$. Then a_1, a_2, &c. being the discordances, the probable error of a result of weight unity is equal to

$$K\sqrt{\frac{s}{N}\frac{n_1a_1^2+n_2a_2^2+\ \ldots}{s-1}}$$

and the probable error of the final value is

$$K\sqrt{\frac{n_1a_1^2+n_2a_2^2+\ \ldots}{N(s-1)}}=C$$

Now $N-r$ is less than $N-1$, therefore

$$\frac{K}{\sqrt{N}}\sqrt{\frac{\Sigma(v^2)}{N-r}} \text{ is greater than } \frac{K}{\sqrt{N}}\sqrt{\frac{\Sigma(v^2)}{N-1}},$$

and therefore, in consequence of (b), still more is

$$C \text{ greater than } \frac{K}{\sqrt{N}}\sqrt{\frac{\Sigma(v^2)}{N-1}}.$$

But if we suppose the residuals v_{11}, v_{12}, &c. to be due to the uncertainty in x alone, and that the values of y and z are absolutely correct, then the quantity

$$\frac{K}{\sqrt{N}}\sqrt{\frac{\Sigma v^2}{N-1}}$$

is the probable error in the resulting value of x as derived from the first direct solution on this latter hypothesis.

Thus we find the remarkable result, that Dr. Gill has reduced the apparent probable error of an observation of weight unity by the device of applying constant corrections in groups, at the expense of throwing on the resulting value of x a larger degree of uncertainty than would have resulted if we had supposed that the original residuals were wholly due to errors in that quantity, the values of y and z being free from error.

In point of fact the quantity

$$K\sqrt{\frac{\Sigma(V^2)}{N-R}}$$

is *not* the probable error of a single observation, *it is only one portion of it, and not even the more important portion;* and when Dr. Gill's probable error is correctly computed the apparent superiority of his solution wholly disappears.

The oversight which Dr. Gill has here committed is, I think, more common than one would at first suppose, and it is, perhaps, to some extent to errors of this sort that we may

attribute the anomaly of observations by different observers or under different conditions leading to results differing by hundredths or even tenths of a second, while the probable error of each is exhibited as a few units in the third place.

In the case before us the error arises from the hypothetical nature of these corrections having been overlooked in computing the probable error of an observation.

In the fourth part of Airy's *Theory of Errors of Observations* he shows how the existence of constant errors affecting groups of observations is to be established, and points out how the probable error is to be deduced on that hypothesis. Airy, it is true, only considers the case of a single variable, but the principles there laid down are easily extended to the case of any number of variables. See also Chauvenet's *Spherical and Practical Astronomy*, vol. ii. p. 508.

On p. 107, having pointed out how the existence of such constant errors is to be established, Airy goes on to say: "We are not justified for each of these limited groups in assuming a value for the constant error, or variable error of the second class, applicable to that group; we must treat it as an uncertain quantity, and ascertain the combination weights and the probable error and theoretical weight of final result under the effects of the errors of the two classes by an operation analogous to those which are applied when the errors are of only one class."

To investigate the most probable values of the unknown quantities and their probable errors, we suppose that the probable error is the same, or is relatively known, for each observation of a group.

If we have reason to suspect the existence of systematic errors affecting groups of observations, the only legitimate method of proceeding seems to be as follows.

Solve each set of equations separately by the method of least squares. In this way we obtain as many separate values of each variable as there are groups, with their relative weights, the probable error of a single observation of weight unity in each group, and the probable error of each value of each variable. Then, if we introduce the hypothesis of a systematic error affecting each group of observations, we examine by the theory of errors in the way Airy has shown for a single variable, whether such a systematic error is admissible or not. If the result of the examination is in favour of this hypothesis, we investigate the amount of the constant error, or "variable error of the second class," as Airy calls it, for each group, and deduce the most probable value of each variable under the influence of both classes of errors, and the probable error of each final result.

Dr. Gill's method of applying a constant correction in each group, and solving by the method of least squares applied to all the equations of condition thus obtained is quite inadmissible, as may be seen from the following considerations.

Let us suppose we have a series of equations of condition free

from systematic errors, and affected only by the ordinary irregular errors to which the method of Gauss is strictly applicable.

Then, using the same notation as on p. 263, we have:

$$\left.\begin{array}{c} x+b_{11}y+c_{11}z+n_{11}=0 \\ x+b_{12}y+c_{12}z+n_{12}=0 \\ \&c. \quad \&c. \\ x+b_{21}y+c_{21}z+n_{21}=0 \\ \&c. \quad \&c. \end{array}\right\} \quad \ldots\ldots\ldots \quad (A)$$

We have the normal equations

$$\begin{array}{l} N\ .x+\Sigma b\ \ .y+\Sigma c\ \ .z+\Sigma n\ \ =0 \\ \Sigma b.x+\Sigma(b^2).y+\Sigma(bc).z+\Sigma(bn)=0 \\ \Sigma c.x+\Sigma(bc).y+\Sigma(c^2).z+\Sigma(cn)=0 \end{array}$$

and the most probable value of z is, using the determinant notation as in Glaisher's paper in the *Monthly Notices*, vol. xxxiv.

$$z=\begin{vmatrix} N, & \Sigma b, & \Sigma n \\ \Sigma b, & \Sigma(b^2), & \Sigma(bn) \\ \Sigma c, & \Sigma(bc), & \Sigma(cn) \end{vmatrix} \div \begin{vmatrix} N, & \Sigma b, & \Sigma c \\ \Sigma b, & \Sigma(b^2), & \Sigma(bc) \\ \Sigma c, & \Sigma(bc), & \Sigma(c^2) \end{vmatrix}$$

Now to the first group of equations let us deliberately apply a constant error a_1; to the second group an error a_2, and so on.

$$\begin{array}{lccl} \text{Then } n_{11} & \text{will become} & n_{11}+a_1=N_{11}, & \text{say} \\ n_{12} & ,, \quad ,, & n_{12}+a_1=N_{12}, & ,, \\ & \&c. & \&c. & \\ n_{21} & ,, \quad ,, & n_{21}+a_2=N_{21} & ,, \\ & \text{and so on.} & & \end{array}$$

And the equations of condition, as they are presented to us for solution, become

$$\left.\begin{array}{c} x+b_{11}y+c_{11}z+N_{11}=0 \\ x+b_{12}y+c_{12}z+N_{12}=0 \\ \&c \\ x+b_{21}y+c_{21}z+N_{21}=0 \\ \&c. \end{array}\right\} \quad \ldots\ldots\ldots \quad (B)$$

But the most probable values of the variables are those found from the equations (A) by the method of least squares. These could be obtained from the equations (B) by subtracting a_1 from the first, a_2 from the second, and so for the other groups. We do not,

however, know the values of a_1, a_2, &c. But putting $x_1=x-a_1$, $x_2=x-a_2$, &c. the true equations of condition become

$$\left.\begin{array}{c} x_1+b_{11}y+c_{11}z+N_{11}=0 \\ x_1+b_{12}y+c_{12}z+N_{12}=0 \\ \&c. \\ x_2+b_{21}y+c_{21}z+N_{21}=0 \\ \&c. \end{array}\right\} \quad \ldots\ldots\ldots \quad (C)$$

These are the equations of condition as obtained by Dr. Gill, and we have to ascertain whether, treated by Dr. Gill's method, they will lead to the same result for z as the equations (A).

If we have four groups containing l_1, l_2, l_3, and l_4 observations respectively, the normal equations are :—

$$\begin{array}{l} l_1x_1 \qquad\qquad\qquad\qquad +\Sigma b_1\,.\,y+\Sigma c_1\,.\,z+\Sigma N_1=0 \\ \qquad l_2x_2 \qquad\qquad\qquad +\Sigma b_2\,.\,y+\Sigma c_2\,.\,z+\Sigma N_2=0 \\ \qquad\qquad l_3x_3 \qquad\quad +\Sigma b_3\,.\,y+\Sigma c_3\,.\,z+\Sigma N_3=0 \\ \qquad\qquad\qquad l_4x_4+\Sigma b_4\,.\,y+\Sigma c_4\,.\,z+\Sigma N_4=0 \\ \Sigma b_1\,.\,x_1+\Sigma b_2\,.\,x_2+\Sigma b_3\,.\,x_3+\Sigma b_4\,.\,x_4+\Sigma(b^2)\,.\,y+\Sigma(bc)\,.\,z+\Sigma(bN)=0 \\ \Sigma c_1\,.\,x_1+\Sigma c_2\,.\,x_2+\Sigma c_3\,.\,x_3+\Sigma c_4\,.\,x_4+\Sigma(bc)\,.\,y+\Sigma(c^2)\,.\,z+\Sigma(cN)=0 \end{array}$$

And the value of z is

$$z_1=\begin{vmatrix} l_1, & 0, & 0, & 0, & \Sigma b_1, & \Sigma N_1 \\ 0, & l_2, & 0, & 0, & \Sigma b_2, & \Sigma N_2 \\ 0, & 0, & l_3, & 0, & \Sigma b_3, & \Sigma N_3 \\ 0, & 0, & 0, & l_4, & \Sigma b_4, & \Sigma N_4 \\ \Sigma b_1, & \Sigma b_2, & \Sigma b_3, & \Sigma b_4, & \Sigma(b^2), & \Sigma(bN) \\ \Sigma c_1, & \Sigma c_2, & \Sigma c_3, & \Sigma c_4, & \Sigma(bc), & \Sigma(cN), \end{vmatrix} \div \begin{vmatrix} l_1, & 0, & 0, & 0, & \Sigma b_1, & \Sigma c_1 \\ 0, & l_2, & 0, & 0, & \Sigma b_2, & \Sigma c_2 \\ 0, & 0, & l_3, & 0, & \Sigma b_3, & \Sigma c_3 \\ 0, & 0, & 0, & l_4, & \Sigma b_4, & \Sigma c_4 \\ \Sigma b_1, & \Sigma b_2, & \Sigma b_3, & \Sigma b_4, & \Sigma(b^2), & \Sigma(bc) \\ \Sigma c_1, & \Sigma c_2, & \Sigma c_3, & \Sigma c_4, & \Sigma(bc), & \Sigma(c^2) \end{vmatrix}$$

But

$$\begin{array}{l} \Sigma N_1=\Sigma n_1+l_1a_1 \\ \Sigma N_2=\Sigma n_2+l_2a_2 \\ \Sigma N_3=\Sigma n_3+l_3a_3 \\ \Sigma N_4=\Sigma n_4+l_4a_4 \\ \Sigma(bN)=\Sigma(bn)+\Sigma b_1\,.\,a_1+\Sigma b_2\,.\,a_2+\Sigma b_3\,.\,a_3+\Sigma b_4\,.\,a_4 \\ \Sigma(cN)=\Sigma(cn)+\Sigma c_1\,.\,a_1+\Sigma c_2\,.\,a_2+\Sigma c_3\,.\,a_3+\Sigma c_4\,.\,a_4. \end{array}$$

Hence multiplying the first four columns by a_1, a_2, a_3, and a_4 respectively, and subtracting from the last, this expression becomes

$$z_1=\begin{vmatrix} l_1, & 0, & 0, & 0. & \Sigma b_1 & \Sigma n_1 \\ 0, & l_2, & 0, & 0, & \Sigma b_2, & \Sigma n_2 \\ 0, & 0, & l_3, & 0, & \Sigma b_3 & \Sigma n_3 \\ 0, & 0, & 0, & l_4, & \Sigma b_4, & \Sigma n_4 \\ \Sigma b_1, & \Sigma b_2, & \Sigma b_3, & \Sigma b_4, & \Sigma(b^2), & \Sigma(bn) \\ \Sigma c_1, & \Sigma c_2, & \Sigma c_3, & \Sigma c_4, & \Sigma(bc), & \Sigma(cn) \end{vmatrix} \div \begin{vmatrix} l_1, & 0, & 0, & 0, & \Sigma b_1, & \Sigma c_1 \\ 0, & l_2, & 0, & 0, & \Sigma b_2, & \Sigma c_2 \\ 0, & 0, & l_3, & 0, & \Sigma b_3, & \Sigma c_3 \\ 0, & 0, & 0, & l_4, & \Sigma b_4, & \Sigma c_4 \\ \Sigma b_1, & \Sigma b_2, & \Sigma b_3, & \Sigma b_4, & \Sigma(b^2), & \Sigma(bc) \\ \Sigma c_1, & \Sigma c_2, & \Sigma c_3, & \Sigma c_4. & \Sigma(bc), & \Sigma(c^2) \end{vmatrix}$$

Expanding these determinants each in terms of the minors of its fifth and sixth rows, this expression becomes after a slight transformation

$$
l_1l_2l_3l_4\begin{vmatrix}\Sigma b^2, & \Sigma(bn)\\ \Sigma(bc), & \Sigma(cn)\end{vmatrix}
+l_2l_3l_4\begin{vmatrix}0, & \Sigma b_1, & \Sigma n_1\\ \Sigma b_1, & \Sigma(b^2), & \Sigma(bn)\\ \Sigma c_1, & \Sigma(bc), & \Sigma(cn)\end{vmatrix}
+l_1l_3l_4\begin{vmatrix}0, & \Sigma b_2, & \Sigma n_2\\ \Sigma b_2, & \Sigma(b^2), & \Sigma(bn)\\ \Sigma c_2, & \Sigma(bc), & \Sigma(cn)\end{vmatrix}
$$

$$
+l_1l_2l_4\begin{vmatrix}0, & \Sigma b_3, & \Sigma n_3\\ \Sigma b_3, & \Sigma(b^2), & \Sigma(bn)\\ \Sigma c_3, & \Sigma(bc), & \Sigma(cn)\end{vmatrix}
+l_1l_2l_3\begin{vmatrix}0, & \Sigma b_4, & \Sigma n_4\\ \Sigma b_4, & \Sigma(b^2), & \Sigma(bn)\\ \Sigma c_4, & \Sigma(bc), & \Sigma(cn)\end{vmatrix}
+l_1l_2\begin{vmatrix}0, & 0, & \Sigma b_3, & \Sigma n_3\\ 0, & 0, & \Sigma b_4, & \Sigma n_4\\ \Sigma b_3, & \Sigma b_4, & 0, & 0\\ \Sigma c_3, & \Sigma c_4, & 0, & 0\end{vmatrix}
$$

$$
+l_1l_3\begin{vmatrix}0, & 0, & \Sigma b_2, & \Sigma n_2\\ 0, & 0, & \Sigma b_4, & \Sigma n_4\\ \Sigma b_2, & \Sigma b_4, & 0, & 0\\ \Sigma c_2, & \Sigma c_4, & 0, & 0\end{vmatrix}
+l_1l_4\begin{vmatrix}0, & 0, & \Sigma b_2, & \Sigma n_2\\ 0, & 0, & \Sigma b_3, & \Sigma n_3\\ \Sigma b_2, & \Sigma b_3, & 0, & 0,\\ \Sigma c_2, & \Sigma c_3, & 0, & 0,\end{vmatrix}
+l_2l_3\begin{vmatrix}0, & 0, & \Sigma b_1, & \Sigma n_1\\ 0, & 0, & \Sigma b_4, & \Sigma n_4\\ \Sigma b_1, & \Sigma b_4, & 0, & 0\\ \Sigma c_3, & \Sigma c_4, & 0, & 0\end{vmatrix}
$$

$$
+l_2l_4\begin{vmatrix}0, & 0, & \Sigma b_1, & \Sigma n_1\\ 0, & 0, & \Sigma b_3, & \Sigma n_3\\ \Sigma b_1, & \Sigma b_3, & 0, & 0\\ \Sigma c_1, & \Sigma c_3, & 0, & 0\end{vmatrix}
+l_3l_4\begin{vmatrix}0, & 0, & \Sigma b_1, & \Sigma n_1\\ 0, & 0, & \Sigma b_2, & \Sigma n_2\\ \Sigma b_1, & \Sigma b_2, & 0, & 0\\ \Sigma c_1, & \Sigma c_2, & 0, & 0\end{vmatrix}
$$

Divided by the expression into which this transforms when c is substituted for n throughout.

But the value of z as derived from the equations (A) is

$$
\begin{vmatrix}\mathrm{N}, & \Sigma b, & \Sigma n\\ \Sigma b, & \Sigma(b^2), & \Sigma(bn)\\ \Sigma c, & \Sigma(bc), & \Sigma(cn)\end{vmatrix}
$$

Divided by the expression into which this transforms when c is substituted for n.

Now, the quantities l_1, l_2, l_3, l_4, and N bear no relation to the coefficients of the normal equations, and we know that if α, β, γ, δ, ϵ and α', β', γ', δ', ϵ' are so related that for any arbitrary multipliers p, q, r, s, t

$$\frac{p\alpha+q\beta+r\gamma}{p\alpha'+q\beta'+r\gamma'}=\frac{s\delta+t\epsilon}{s\delta'+t\epsilon'}$$

then

$$\frac{\alpha}{\alpha'}=\frac{\beta}{\beta'}=\frac{\gamma}{\gamma'}=\frac{\delta}{\delta'}=\frac{\epsilon}{\epsilon'}$$

From this it follows that the two values of z will agree if

$$\frac{n_{11}}{c_{11}}=\frac{n_{12}}{c_{12}}=\frac{n_{13}}{c_{13}}=\&c.=\frac{n_{21}}{c_{21}}=\frac{n_{22}}{c_{22}}=\&c.=\frac{n_{31}}{c_{31}}\ \&c.$$

Apart, then, from a very complicated relation between the numbers of the equations in each group and the coefficients of

the normal equations, which we have no right to assume, this seems to be the only condition of a general character that the method under consideration may be allowable.

It is, however, quite different if we treat each group of equations separately. Then we get no contradiction, but the resulting value of z, as deduced from each group affected with constant error, is the same as if the constant error did not exist. This almost obvious proposition may be easily demonstrated as follows:

If we confine our attention to the first group, and suppose that each equation in this is affected by a systematic error, which for the sake of greater generality we may take to be of the form

$$a_1 + b_{11}\beta_1\,;\ a_1 + b_{12}\beta_1,\ \text{\&c.};$$

and if we put

$$N_{11} = n_{11} + a_1 + b_{11}\beta_1\,;\ N_{12} = n_{12} + a_1 + b_{12}\beta_1\,;\ \text{\&c.},$$

the equations as presented to us for solution become

$$x + b_{11}y + c_{11}z + N_{11} = 0,\ \text{\&c.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(D)}$$

but the equations of condition unaffected by systematic error may be written

$$x + b_{11}y + c_{11}z + N_{11} - a_1 - b_{11}\beta_1 = 0,\ \text{\&c.}$$

Hence if we put $x_1 = x - a_1$; $y_1 = y - \beta_1$, we get

$$x_1 + b_{11}y_1 + c_{11}z + N_{11} = 0,$$

which are the true equations of condition, although N_{11}, &c., are affected with systematic errors.

The normal equations thus become

$$\begin{aligned} l_1x_1 + \Sigma b_1 \quad . \, y_1 + \Sigma c_1 \quad . \, z + \Sigma N_1 \quad &= 0 \\ \Sigma b_1 \, . \, x_1 + \Sigma(b_1^2) \, . \, y_1 + \Sigma(bc_1) \, . \, z + \Sigma(bN_1) &= 0 \\ \Sigma c_1 \, . \, x_1 + \Sigma(bc_1) \, . \, y_1 + \Sigma(c_1^2) \, . \, z + \Sigma(cN_1) &= 0 \end{aligned}$$

from which we deduce

$$z = \begin{vmatrix} l_1, & \Sigma b_1, & \Sigma N_1 \\ \Sigma b_1, & \Sigma(b_1^2), & \Sigma(bN_1) \\ \Sigma c_1, & \Sigma(bc_1), & \Sigma(cN_1) \end{vmatrix} \div \begin{vmatrix} l_1, & \Sigma b_1, & \Sigma c_1 \\ \Sigma b_1, & \Sigma(b_1^2), & \Sigma(bc_1) \\ \Sigma c_1, & \Sigma(bc_1), & \Sigma(c_1^2) \end{vmatrix}$$

which transforms into

$$z = \begin{vmatrix} l_1, & \Sigma b_1, & \Sigma n_1 \\ \Sigma b_1, & \Sigma(b_1^2), & \Sigma(bn_1) \\ \Sigma c_1, & \Sigma(bc_1), & \Sigma(cn_1) \end{vmatrix} \div \begin{vmatrix} l_1, & \Sigma b_1, & \Sigma c_1 \\ \Sigma b_1, & \Sigma(b_1^2), & \Sigma(bc_1) \\ \Sigma c_1, & \Sigma(bc_1), & \Sigma(c_1^2) \end{vmatrix}$$

which is the same expression as we should have obtained from the original equations of condition.

We thus see that if each group is affected by a constant error, or in addition with an error varying with the time, the factor (β) of which varies from group to group, then by solving each group of equations separately we eliminate entirely the effect of this systematic error from the values of z, and obtain the same values for this quantity as we should have found had we been able to determine this error and eliminate its effect from the equations of condition. If there is a further term in the expression for the error of the form $c_{11}\gamma_1$, $c_{12}\gamma_1$ . . . $c_{21}\gamma_2$, $c_{22}\gamma_2$ . . . then we shall no longer be able to eliminate it in the separate groups; we shall, in fact, not be able to separate γ_1 from z in the first group, γ_2 from z in the second, and so on. We shall thus get as many values of z as there are groups, and the final value of z will be found by combining these in such a way that its probable error may be the least possible.

Should the systematic error not be represented, or not wholly represented, by the expressions $a_1+b_{11}\beta_1+c_{11}\gamma_1$, &c., $a_2+b_{21}\beta_2+c_{21}\gamma_2$, &c., there will still be an outstanding effect which we cannot eliminate, but its trend or law is presumably wholly unknown to us, and its effect will be indistinguishable from the ordinary errors of observation.

We see, therefore, that whatever be the law of systematic error we must solve each group of equations separately, and investigate the weight with which the individual results are to be combined, so as to make the probable error arising from every source a minimum.

In the case of Dr. Gill's equations of condition, the coefficient of x is unity, but for the sake of generality we shall consider a series of equations of the form

$$ax+by+cz+n=0.$$

If we suppose these equations to be divided into groups in each of which every observation is affected by a systematic error, the procedure will be similar whatever be the numbers of the variables or of the groups—we find the following quantities for each group in the ordinary way by the application of the principle of least squares:—

Group.	I.	II.
Probable error of equation of weight = 1	e_1	e_2
Value of x	x_1	x_2
Weight of x	p_{x1}	p_{x2}
Probable error of x	e_{x1}	e_{x2}
Value of y	y_1	y_2
Weight of y	p_{y1}	p_{y2}
Probable error of y	e_{y1}	e_{y2}
Value of z	z_1	z_2
Weight of z	p_{z1}	p_{z2}
Probable error of z	e_{z1}	e_{z2} &c. &c.

Now, to decide whether the separate values of any of these variables are affected by systematic errors we proceed as Airy directs in the case of a single variable.

The next few paragraphs are, indeed, almost word for word taken from his *Theory of Errors of Observations.*

We take the weighted mean of the separate values, the weights being inversely proportional to the squares of their probable errors. This mean may be provisionally regarded as "final result." The "Final Result" is to be subtracted from the "Result for each Group," and the remainder is the "Discordance for each Group."

Now we treat the discordances as being themselves errors, and investigate by the theory of errors the "Mean Discordance;" and the "Probable Error of Mean Discordance" is then found in the way that Airy indicates.

Thus we have (1) a numerical value of mean discordance, and (2) a number expressing the probable error in the determination of that numerical value.

If (2) exceeds (1) there is no justification for the assumption of a discordance, that is, of a systematic error. If (2) is much less than (1) it appears equally clear that a systematic error must be assumed to exist, and (1) or any value near it may be taken for "mean discordance." The "*probable* discordance" or "*probable* systematic error" will then be found by multiplying this by 0·8454.

Now we are not justified in assuming that the "discordance for each group," found above, is *actually* the systematic error or "variable error of the second class" applicable to that group; we must treat these errors as uncertain quantities and ascertain the combination weights, and the probable errors and theoretical weights of the final results under the effects of the errors of the two classes.

Let the *actual* values of the errors of the second class affecting one of the variables, say x, in the successive groups be C_1, C_2, C_3, C_4; the probable error of each being c. And in the first group let the *actual* values of the errors of the first class (or ordinary errors) affecting successive observations be E_{11}, E_{12}, E_{13}, &c.; for those in the second group E_{21}, E_{22}, &c., and so on. Their probable values being e_{11}, e_{12}, e_{13}, &c., e_{21}, e_{22}, &c.

The actual error of the first class in one of the separate values of the variable, say the first, consists of a series of multiples of the quantities E_{11}, E_{12}, &c.; hence we may write the total *actual* error affecting x_1 as

$$C_1 + a_{11}E_{11} + a_{12}E_{12} + a_{13}E_{13} + \&c.$$

In order to find a final value of x we assume four undetermined multipliers, l_1, l_2, l_3, and l_4, and take

$$x = \frac{l_1x_1 + l_2x_2 + l_3x_3 + l_4x_4}{l_1 + l_2 + l_3 + l_4} = \frac{\Sigma lx}{\Sigma l},$$

and the most probable value of x is that computed with the quantities l_1, l_2, l_3, l_4, for which the resulting probable error of x is a minimum.

To find these quantities we notice that the actual error in x is

$$\frac{l_1C_1+l_2C_2+l_3C_3+l_4C_4}{\Sigma l}+\frac{l_1}{\Sigma l}(a_{11}E_{11}+a_{12}E_{12}+\&c.)+\frac{l_2}{\Sigma l}(a_{21}E_{21}+a_{22}E_{22}+\&c.)+\&c.$$

Hence the square of the probable error in x is

$$\frac{l_1^2+l_2^2+l_3^2+l_4^2}{(\Sigma l)^2}c^2+\frac{l_1^2}{(\Sigma l)^2}\{a_{11}^2e_{11}^2+a_{12}^2e_{12}^2+a_{13}^2e_{13}^2+\&c.\}$$
$$+\frac{l_2^2}{(\Sigma l)^2}\{a_{21}^2e_{21}^2+\&c.\}+\&c.$$

But $a_{11}^2e^2_{11}+a_{12}^2e_{12}^2+\&c.$ is the square of the probable error of x, as deduced from the first group of observations alone; $a_{21}^2e_{21}^2+a_{22}^2e_{22}^2+\&c.$ is the square of the probable error of x, as deduced from the second group of observations alone, and so on. But these are equal to $\frac{e_1^2}{p_{x1}}$, $\frac{e_2^2}{p_{x2}}$, and so on.

Hence, we find the square of the probable error of x is

$$\frac{l_1^2+l_2^2+l_3^2+l_4^2}{(\Sigma l)^2}\cdot c^2+\frac{l_1^2}{(\Sigma l)^2}\cdot\frac{e_1^2}{p_{x1}}+\frac{l_2^2}{(\Sigma l)^2}\cdot\frac{e_2^2}{p_{x2}}+\&c.$$

and this is to be a minimum.

Differentiating with respect to each of the quantities l_1, l_2, l_3 and l_4, and putting the differential coefficients equal to zero we find, putting A for an indeterminate constant,

$$l_1c^2+l_1\frac{e_1^2}{p_{x1}}=A.$$

Therefore,

$$l_1=\frac{A}{c^2+\frac{e_1^2}{p_{x1}}}$$

similarly

$$l_2=\frac{A}{c^2+\frac{e_2^2}{p_{x2}}}$$

with similar values for l_3 and l_4.

These are the combination factors for each of the separate results. If c is zero, they reduce to the ordinary form, viz., $\frac{p_{x1}}{e_1^2}$, $\frac{p_{x2}}{e_2^2}$, &c., or to the reciprocals of the squares of the probable errors of the individual results.

The square of the probable error of x found above may be written

$$\frac{l_1^2}{(\Sigma l)^2}\left\{c^2+\frac{e_1^2}{p_{x1}}\right\}+\frac{l_2^2}{(\Sigma l)^2}\left\{c^2+\frac{e_2^2}{p_{x2}}\right\}+\frac{l_3^2}{(\Sigma l)^2}\left\{c^2+\frac{e_3^2}{p_{x3}}\right\}+\frac{l_4^2}{(\Sigma l)^2}\left\{c^2+\frac{e_4^2}{p_{x4}}\right\}$$

or, if we substitute the values found above for l_1, l_2, l_3 and l_4,

$$\frac{1}{e_x^2} = \frac{1}{c^2 + \frac{e_1^2}{p_{x1}}} + \frac{1}{c^2 + \frac{e_2^2}{p_{x2}}} + \frac{1}{c^2 + \frac{e_3^2}{p_{x3}}} + \frac{1}{c^2 + \frac{e_4^2}{p_{x4}}},$$

where e_x denotes the probable error of the final value of x.

From the method of deduction it is obvious that we have similar expressions for y and z, viz.:

$$\frac{1}{e_y^2} = \frac{1}{d^2 + \frac{e_1^2}{p_{y1}}} + \frac{1}{d^2 + \frac{e_2^2}{p_{y2}}} + \frac{1}{d^2 + \frac{e_3^2}{p_{y3}}} + \frac{1}{d^2 + \frac{e_4^2}{p_{y4}}},$$

and

$$\frac{1}{e_z^2} = \frac{1}{f^2 + \frac{e_1^2}{p_{z1}}} + \frac{1}{f^2 + \frac{e_2^2}{p_{z2}}} + \frac{1}{f^2 + \frac{e_3^2}{p_{z3}}} + \frac{1}{f^2 + \frac{e_4^2}{p_{z4}}},$$

in which d and f are the probable constant errors affecting the separate values of y and z. The combination factors are the separate fractions in these expressions.

We thus see that, in order to combine the results for any physical quantity obtained from different groups of observations which may possibly be affected by discordances which are constant in each group, we do not require to know the original equations from which each separate result is obtained in order to deduce the most probable result. The only quantities we need are the most probable results as deduced from each series by the method of least squares, the probable error of an observation of weight unity in each series, and the weight of the resulting values relatively to that of an observation of weight unity.

We have now to solve the equations of condition deduced from Dr. Gill's observations in accordance with the theory above developed.

First we solve the four groups of equations separately by the method of least squares, and we find the following results:—

TABLE B.

Group.	I.	II.	III.	IV.
e	R ±0·0072	R ±0·0090	R ± 0·0095	R ±0·0144
x	R +0·0075	R +0·0126	R − 0·0182	R +0·0089
p_x	4·657	1·001	20·587	4·280
e_x	R ±0·0033	R ±0·0090	R ± 0·0021	R ±0·0070
y	R +0·0108	R −0·0030	R − 0·0107	R +0·0083
p_y	4·215	3·018	10·724	1·844
e_y	R ±0·0035	R ±0·0052	R ± 0·0029	R ±0·0106
z	R +0·1181	R +0·0912	R + 0·1118	R +0·1129
p_z	2·780	0·850	13·824	3·006
e_z	R ±0·0043	R ±0·0098	R ± 0·0026	R ±0·0083

Let us first consider the values of x. If we give each of the four values a combination-weight inversely proportional to the square of its probable error, we find as the mean value

$$x = -0{\cdot}0089.$$

Hence we have as the discordances from the mean

$$\Delta_1 = +0{\cdot}0164,$$
$$\Delta_2 = +0{\cdot}0215,$$
$$\Delta_3 = -0{\cdot}0093,$$
$$\Delta_4 = +0{\cdot}0178,$$

and the mean discordance, as defined by Airy, p. 19, is equal to

$$\Delta = 0{\cdot}0139.$$

Now the actual error of the first class in x_1 being E_1; of x_2 being E_2, &c.; the actual error of x will be $\frac{\Sigma(p_x \times E)}{\Sigma(p_x)}$. Hence, the actual error of Δ_1 is $E_1 - \frac{\Sigma(p_x \times E)}{E(p_x)}$; of Δ_2 is $E_2 - \frac{\Sigma(p_x E)}{\Sigma(p_x)}$, &c. In this case, $\Delta = \frac{1}{6}(\Delta_1 + \Delta_2 + \Delta_4) - \frac{1}{2}\Delta_3$, and therefore the actual error in Δ is

$$\tfrac{1}{6}(E_1 + E_2 + E_4) - \tfrac{1}{2}E_3,$$

and consequently, if e_Δ denotes the probable error of Δ, we have

$$e_\Delta^2 = \tfrac{1}{36}(e_{x_1}^2 + e_{x_2}^2 + e_{x_4}^2) + \tfrac{1}{4}e_{x_3}^2.$$

[It might perhaps be better to take the mean discordance as defined by Chauvenet, viz., as the mean of the discordances without regard to sign. This would give us in this case $\Delta = 0{\cdot}0162$, and in all cases the probable error of Δ would then be—

$$e_\Delta = \pm\frac{\sqrt{e_{x_1}^2 + e_{x_2}^2 + e_{x_3}^2 + \text{\&c.}}}{8}.]$$

Putting in the values of e_{x_1}, &c. from *Table B*, and extracting the square root, we find $e_\Delta = \pm 0{\cdot}0022$. Hence, we have (1) the "Mean Discordance" equal to $0{\cdot}0139$, and (2), its probable error equal to $\pm 0{\cdot}0022$. In this case the probable error of Δ is so much smaller than Δ itself that we are probably justified in assuming the reality of Δ.

We thus find for the "Mean Discordance," or "Mean Error of the Second Class," the quantity $0{\cdot}0139$, which multiplied by the factor $0{\cdot}8454$ gives us as the "Probable Error of the Second Class"

$$c = \pm 0{\cdot}0117.$$

We have next to compute the combination factors $1/(c^2+e_{z_1}^2)$, &c. Thus we find—

$$1/(c^2+e_{x_1}^2) = 6756$$
$$1/(c^2+e_{x_2}^2) = 4590$$
$$1/(c^2+e_{x_3}^2) = 7079$$

and

$$1/(c^2+e_{x_4}^2) = \underline{5395}$$
$$\therefore 1/e_x^2 = 23820 \quad \therefore e_x = \pm 0^{R}\cdot0065$$

And therefore $x = +0^{R}\cdot0012 \pm 0^{R}\cdot0065 = +0''\cdot015 \pm 0''\cdot084$.

Again let us examine the most probable value of z. Proceeding as in the case of x, we find

$$z = +0\cdot1124,$$

and for the discordances from this mean we have

$$\Delta_1 = -0\cdot0057$$
$$\Delta_2 = +0\cdot0212$$
$$\Delta_3 = +0\cdot0006$$
$$\Delta_4 = -0\cdot0005$$

and the mean discordance is equal to 0·0070.

In this case $\Delta = \frac{1}{4}(\Delta_2+\Delta_3-\Delta_1-\Delta_4)$, and therefore we find that

$$e_\Delta^2 = \tfrac{1}{16}(e_{z_1}^2+e_{z_2}^2+e_{z_3}^2+e_{z_4}^2)$$

Substituting the values of e_{z_1}, &c. from *Table B*, and extracting the square root, we have $e_\Delta = \pm 0\cdot0034$.

Hence we have for the "Mean Error of the Second Class" in z

$$\Delta = 0\cdot0070 \pm 0\cdot0034.$$

The magnitude of the probable error here, being just less than half that of Δ itself, would seem to point to the existence of systematic errors in the values of z, though not so convincingly as in the case of x. If we admit its existence, we have as the "Probable Error of the Second Class" in z

$$f = \pm 0\cdot0059.$$

Assuming this value for f, we have next to compute the combination factors as before, and we find—

$$1/(f^2+e_{z_1}^2) = 18706$$
$$1/(f^2+e_{z_2}^2) = 7683$$
$$1/(f^2+e_{z_3}^2) = 24190$$
$$1/(f^2+e_{z_4}^2) = \underline{9635}$$
$$1/e_z^2 = 60214 \quad \therefore e_z = \pm 0\cdot0041,$$

and therefore—

$$z = +0^{R}\cdot1113 \pm 0^{R}\cdot0041 = 0''\cdot761 \pm 0''\cdot028.$$

If we do not admit the existence of a systematic error in the values of z, we must put $f=0$,* and we get simply—

$$\frac{1}{e_z^2}=\frac{1}{e_{z_1}^2}+\frac{1}{e_{z_2}^2}+\frac{1}{e_{z_3}^2}+\frac{1}{e_{z_4}^2}=226941$$

$$\therefore \frac{1}{e_z}=\pm 476\cdot 4$$

and

$$\therefore e_z=\pm 0\cdot 0021.$$

We thus get the two solutions—

(1) Assuming the existence of systematic errors affecting the values of z in each group,

$$\pi = 0\overset{\text{R}}{\cdot}1113 \pm 0\overset{\text{R}}{\cdot}0041 = 0''\!\cdot 761 \pm 0''\!\cdot 028,$$

or (2) supposing that there is no such systematic error—

$$\pi = 0\overset{\text{R}}{\cdot}1124 \pm 0\overset{\text{R}}{\cdot}0021 = 0''\!\cdot 769 \pm 0''\!\cdot 014.$$

And now let us turn once more to Dr. Gill's solution. It is not very clear what the probable error of an observation really is. It is certainly not permissible to postulate the existence of unknown errors in the equations, and then to ignore them in computing the probable error. If we admit them at all we must consider them as uncertain errors, and treat them as such.

Dr. Gill supposes a constant error a_1 to exist in each equation of the first group; a constant error a_2 in each equation of the second group, and so on, which, in combination with x, give him four quantities—

$$x_{\prime}=x+a_1;\ x_{\prime\prime}=x+a_2;\ x_{\prime\prime\prime}=x+a_3;\ \text{and}\ x_{\prime\prime\prime\prime}=x+a_4.$$

Now, if we treat these as we did the four values of x in the above separate solutions, we shall be able to obtain a "Mean Discordance" and a "Probable Constant Error" as before. Combining the quantities $x_{\prime}$, $x_{\prime\prime}$, &c., with the weights as given by Dr. Gill, a mean value of x is obtained, which we subtract from each of the individual values, and thus obtain a discordance for each group. From these we form the "Mean Discordance," and then, multiplying by 0·8454, we get the "Probable Constant Error."

* It is not, however, by any means clear that we are at liberty to put $f=0$, and I am inclined to think that, having admitted the existence of systematic errors affecting one of the variables, we must treat the discordances in the separate values of the others as being due to the same cause.

Thus

$x_{,} = +0{\cdot}0178$	Weight	$17{\cdot}2$	$\Delta_1 = +0{\cdot}0199$
$x_{,,} = -0{\cdot}0003$	"	$9{\cdot}5$	$\Delta_2 = +0{\cdot}0018$
$x_{,,,} = -0{\cdot}0214$	"	$24{\cdot}7$	$\Delta_3 = -0{\cdot}0193$
$x_{,,,,} = +0{\cdot}0093$	"	$9{\cdot}7$	$\Delta_4 = +0{\cdot}0114$
		$61{\cdot}1$	$\Delta = 0{\cdot}0152$

Hence $x = -0{\cdot}0021$. Subtracting this from $x_{,}$, $x_{,,}$, &c., we find Δ_1 Δ_2, &c., given in the last column, and thus we have—

$$\Delta = \overset{\text{R}}{0{\cdot}0152}.$$

Therefore the "Probable Constant Error" is $\pm 0^{\text{R}}{\cdot}0128$. This is the uncertainty by which the observations are affected in virtue of the constant (but unknown) errors attaching to the separate groups.

Now if E_{11}, E_{12}, &c., E_{21}, E_{22}, &c., are the errors of the ordinary kind attaching to the observations, we have the total errors of the separate observations in the first group—

$$a_1 + E_{11},\ a_1 + E_{12},\ a_1 + E_{13},\ \&c.;$$

in the second group—

$$a_2 + E_{21},\ a_2 + E_{22},\ a_2 + E_{23},\ \&c.$$

and so on.

If we suppose the probable value of each of the quantities E_{11} E_{12}, &c., E_{21} E_{22}, &c., to be e, and denote the probable constant error by a, it would seem that the square of the probable error of an observation under the effect of both classes of error is equal to

$$a^2 + e^2.$$

But $a = \pm 0^{\text{R}}{\cdot}0128$.

And if for e we take the quantity given by Dr. Gill, namely, $\pm 0^{\text{R}}{\cdot}00918$, we find the probable error of an observation deduced in this way equal to

$$\pm \overset{\text{R}}{0{\cdot}0158},$$

and, therefore, the probable error of z, if deduced in the ordinary way, would be

$$\pm \overset{\text{R}}{0{\cdot}0033}.$$

Hence, we have finally

$$\pi = 0''{\cdot}747 \pm 0''{\cdot}023.$$

It appears, therefore, that the probable error as given by Dr. Gill (viz., $\pm 0''{\cdot}013$) should be increased in the proportion of 13

to 23; or that Dr. Gill has overestimated the weight of his results in the proportion of

$$(23)^2 : (13)^2$$

or approximately as 3 : 1.

But, indeed, the term "probable error" cannot properly be applied to the quantity $\pm 0''\cdot 023$ found above; still less is it applicable to the quantity $\pm 0''\cdot 013$ found by Dr. Gill; for the value $0''\cdot 747$ is not deduced in accordance with the theory of errors, and we have no guarantee that the value $e = 0\cdot 0092$ which we have adopted from Dr. Gill represents the probable error of the first class as deduced from the equations.

As Airy says, in another connection, on the last page of his *Theory of Errors of Observations*, "The computer apparently has had his attention engrossed by 'minimum squares' as the important result to be attained, whereas in reality the satisfying of the equations for minimum squares produces a merely accidental coincidence of results in certain cases (not in all) with those leading to the 'minimum probable error of final result' which is the legitimate object of research."

To recapitulate, then,

(1) If we take the equations as they stand and solve directly, we find

$$\pi = 0''\cdot 819 \pm 0''\cdot 014.$$

Judged by their probable errors alone this and the next one appear the best results of all. The residuals from this solution, however, show it to be inadmissible, and the deduced value of the parallax is probably much too large.

(2) If we admit the possibility of constant errors in each group, and solve by the theory of errors, we have the result

$$\pi = 0''\cdot 769 \pm 0''\cdot 014$$

while the most probable values of the constant errors are not those found by Dr. Gill.

(3) If we admit in addition the possibility of analogous errors affecting the values of π as found from the various groups (for which we have some evidence, although it is not so convincing as in the case of x), we find

$$\pi = 0''\cdot 761 \pm 0''\cdot 028.$$

(4) We have the solution given by me in my former paper, in which the introduction of a term representing the corrections for chromatic dispersion in the atmosphere leads to the value

$$\pi = 0''\cdot 780 \pm 0''\cdot 018$$

and (5) we have Dr. Gill's solution by a method for which there does not seem to be any logical sanction. When we take into

account the fallibility of the corrections which he introduces, this gives us

$$\pi = 0''.747$$

with a probable error of $\pm 0''.023$, as far as it is possible to estimate the probable error at all.

The principal results of this examination are, therefore—

(1) That there appear to be errors affecting each group which are *not* those found by Dr. Gill, and that the evidence is by no means conclusive that they are constant in each group, but that, on the contrary, there is a presumption in favour of a systematic error affecting the separate values of the parallax as deduced from the various groups.

(2) That Dr. Gill's method is inadmissible and his probable error underestimated.

(3) That the most probable value of the parallax as deduced from this series of measures on the assumption of constant errors seems to be $0''.77$, and that the introduction of the correction for chromatic dispersion reduces the value of π from $0''.82$ given by the general solution to $0''.78$ or to within $0''.01$ of this value.

And (4) That the value of π found by Dr. Gill, viz.—$0''.747$, cannot by any logical process be deduced from this series of observations.

The Effect of Latitude Variation on the Ecliptic Investigation. By W. G. Thackeray.

In a former paper, *Monthly Notices* liv. 7, p. 417, Mr. Dyson and myself called attention to the important effect that an error of the nature of Chandler's latitude variation would have on the values derived for the correction to the right ascensions of all stars, or to the value of the obliquity according as its maximum or minimum was near the equinoxes or solstices.

The latitude variation as determined by Dr. Chandler is the resultant of two periods, one annual, the other of about 427 days, varying slightly in period and amplitude, the value of which for Greenwich is determined from the expression (*Astronomical Journal*, xv. 360)—

$$\phi_1 - \phi_0 = r_1 \cos (t - \tau_1)\, \theta + 0''.11 \cos \odot.$$

where ϕ_1 and ϕ_0 are respectively the values of the instantaneous and mean latitude.

$$\tau_1 = 2402327 + 428.6 \text{ E.} + 55 \sin \psi.$$

$$r_1 = 0''.135 + 0''.050 \sin \psi.$$

$$\psi = (t - 2402327)\; 0^\circ.015.$$

θ = the longitude of the fictitious or mean Sun.

Here also will be found a small table giving the values of τ_1, r_1, and θ for each value of E. for the years 1888–1900, and the latitude variation for every 20 days for the years 1893–1896 : in *Astronomical Journal*, xvii. 392, is a table of latitude variation for 1897, and in *Astronomical Journal*, xviii. 426, one for 1898.

In the following table are given latitude variations for the middle of each month as corrections to North Polar distances for the years 1890–1898, the factor for converting the corrections into ecliptic North Polar distance, and in the last column the correction for the annual term alone ($+0''\cdot11 \cos \odot$).

Table of Corrections to N.P.D.'s for Latitude Variation for the Middle of each month for the years 1890–1898.

Day.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	Factor.	Annual Term.
	″	″	″	″	″	″	″	″	″		″
Jan. 15	+·21	+·18	+·06	−·06	−·10	−·04	+·08	+·17	+·18	·98	−·05
Feb. 14	+·22	+·25	+·17	+·04	−·05	−·04	+·06	+·16	+·22	·94	−·09
Mar. 15	+·18	+·27	+·24	+·13	·00	−·04	+·02	+·13	+·22	·92	−·11
April 15	+·09	+·21	+·25	+·19	+·05	−·03	−·03	−·06	+·17	·93	−·10
May 15	−·01	+·12	+·21	+·19	+·08	−·03	−·08	−·03	+·08	·97	−·06
June 15	−·12	−·01	+·13	+·16	+·09	−·02	−·12	−·12	−·03	1·00	−·01
July 15	−·21	−·14	+·02	+·10	+·09	−·02	−·13	−·18	−·14	·99	+·04
Aug. 15	−·22	−·20	−·07	+·02	+·06	·00	−·11	−·21	−·21	·94	+·06
Sept. 15	−·24	−·27	−·19	−·06	+·03	+·02	−·07	−·18	−·24	·92	+·11
Oct. 15	−·17	−·24	−·24	−·12	·00	+·04	−·01	−·10	−·21	·93	+·10
Nov. 15	−·07	−·17	−·23	−·15	−·02	+·07	+·07	−·02	−·13	·97	+·06
Dec. 15	+·07	−·04	−·17	−·14	−·04	+·08	+·13	+·10	−·02	1·00	+·01

Assuming that the error in ecliptic North Polar distance can be represented by the expression—

$$x \times \cos \text{Sun's longitude} + y \times \text{Sun's longitude} + z,$$

and that the Sun's observations for each month can be fairly represented by the middle date of each month, then giving equal weights to each month, it is easy to show that Dr. Chandler's annual term alone produces the following corrections :—

$$x = -0''\cdot10$$
$$y = \cdot00$$
$$z = \cdot00$$

The right ascensions of all stars therefore require to be diminished by $\dfrac{0^s\cdot10}{15 \sin \epsilon}$ or $0^s\cdot016$. This quantity is a constant for all years.

In the same way it can be shown that the effect of the 427-day period for the years 1890–1898 is as follows :—

	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.
	″	″	″	″	″	″	″	″	″
$x =$	−·09	−·15	−·11	+·01	+·11	+·14	+·07	−·04	−·13
$y =$	+·12	+·03	−·10	−·13	−·08	+·03	+·11	+·12	+·05
$z =$	+·02	−·01	−·01	−·02	−·02	·00	+·02	+·02	+·01
	s	s	s	s	s	s	s	s	s
$\frac{x}{15 \sin \epsilon} =$	−·016	−·026	−·019	+·001	+·018	+·023	+·011	−·007	−·022

The effect of the 427-day period is therefore to produce a seven-year period in the observed corrections to the right ascensions of the stars derived from the observations of the Sun, as also in the deduced value of the obliquity (y) similar in amplitude, but varying in epoch, whereas z or the observed distance from the pole to the ecliptic, is not sensibly disturbed.

The 427-day period, as determined by Dr. Chandler, is liable to small fluctuations in amplitude and period, and therefore the above corrections are liable to similar changes for other dates.

On the "Two-Method" Personal Equation.

By Walter W. Bryant.

For several years past it has been part of the routine at Greenwich for the transit observer for the night to observe occasional clock-stars by the eye-and-ear method, so that, in the event of a breakdown of the chronograph or of the observing circuit, all the observers might be in sufficient practice to be able to take good observations by the older method, and also that their personal equations, when using that method, might be approximately known.

Before 1892 it was the rule to deduce a separate clock-error from stars observed eye-and-ear (generally not more than two by one observer on the same night), and to compare this with the clock-error deduced from all the galvanic observations of clock-stars on the same night by the same observer. But as this involves an extra element of uncertainty in the comparison, it was decided in 1892 to compare only the observations made of the same star by the two methods on the same night, thus at once very much simplifying the comparison, and eliminating instrumental error.

Professor Safford has already made use of some of the results in papers presented to the Society, but, as my investigation starts from a different point, and as I am enabled, by the permission of the Astronomer Royal, to include some hitherto unpublished

results for more recent years, I hope to add some interesting matter on this subject.

I had intended to deal with the whole period of six years during which the same rule has been followed, but I find it better to omit 1892, as, of the three observers who have worked regularly since that time with the transit circle, H. was absent on longitude work for a great part of 1892, and A. C. and B. were both in that year too recent as observers to have formed a steady "habit."

First let me note briefly what appears to me to be the psychological meaning of the interval under discussion.

In galvanic observations there are two known methods, called by Professor Newcomb methods A and B, and referred to by psychologists as muscular and sensorial. In the first the observer's attention is concentrated on effecting a coincidence in time between his perception of the bisection of a star, and his making the galvanic contact. In the second the observer waits until the moment of estimated bisection before making contact. Hence, omitting accidental errors, depending partly upon the galvanic current itself and partly on the clock, I should expect the time of a transit to be $t+t_s+t_c$ by method B, and $t+t_s$ by method A, t being the true time, t_s time occupied in seeing or "reaction to light," t_c in making contact; which in method A is to be theoretically zero.

In general, then, I should expect observers by method A to register a little late, and those by method B later still, by the addition of t_c.

In eye-and-ear observations a new suffix is introduced, t_h instead of t_c, where t_h is what the psychologists call the "reaction to sound," hence in this method I should expect, omitting as before accidental errors,

$$\text{Time of Transit}=t+t_s-t_h.$$

There are two methods of eye-and-ear observing, but I see no reason to suspect any difference in the results comparable with the known difference between the two galvanic methods.

Thus the two-method personal equation should be fairly represented for method A by $+t_h$ and for method B by $+t_h+t_c$.

It is to be expected, therefore, that, except in very abnormal cases, observers will make their eye-and-ear transits earlier than galvanic ones, and that those who adopt method B (of whom H. is a well-known example at Greenwich) will have a much larger discordance in the same direction.

It must be borne in mind in comparing the tables which follow that in general the transit-clock is not the same as the sidereal standard used for galvanic observations. Clock Hardy in the transit-room is practically the only one in use for the purpose of eye-and-ear comparisons, and Clock Hardy is a long-suffering machine, exposed to many climatic changes, and with people

often passing to and fro, close to its face, so that it is not fair to expect a constant rate to be maintained. Hence it is vital that a comparison between the two clocks should be made as nearly as possible at the same time as the eye-and-ear observation, if the investigation is to deal with any confidence in very small intervals of time.

It is also important that such comparisons should be made always alike. Clock Hardy is provided with an automatic registration circuit for this purpose, but it sometimes fails owing to bad contacts, faulty insulation, or other causes. So that in many cases some hours elapse between the eye-and-ear observation and the Hardy signal, and in many other cases the signal is sent by hand, in which case the greater part of t_h is liable to disappear, thus reducing the apparent two-method personal equation.

This happened for a long period in 1893, owing to some defect in the wires, and will be referred to later.

It has also sometimes happened that the seconds of Clock Hardy have been alternately long and short, which would cause a systematic error to creep into observations of stars whose eye-and-ear interval is an even number of seconds or thereabout, while those whose eye-and-ear interval is an odd number of seconds would be practically unaffected.

Add to these many other probably small sources of uncertainty, and it will be seen that even if the number of comparisons is large enough to exclude unsystematic errors, it is quite possible that the results will be disappointing.

The following table gives the two-method equation for H., A. C., and B., in each of the first years under discussion, with the number of comparisons and the probable error of a single determination (which has been taken as the unit instead of a single night's determination) :—

	1893.	1894.	1895.	1896.	1897.
H....	$+^{s}.441$	$+^{s}.481$	$+^{s}.438$	$+^{s}.527$	$+^{s}.508$
No. of Stars ...	78	40	80	39	45
Probable Error ...	$\pm^{s}.062$	$\pm^{s}.082$	$\pm^{s}.086$	$\pm^{s}.085$	$\pm^{s}.053$
A. C.	$+^{s}.107$	$+^{s}.093$	$+^{s}.062$	$+^{s}.071$	$+^{s}.082$
No. of Stars ...	69	24	22	17	25
Probable Error ...	$\pm^{s}.065$	$\pm^{s}.051$	$\pm^{s}.059$	$\pm^{s}.065$	$\pm^{s}.072$
B.	$-^{s}.004$	$+^{s}.056$	$+^{s}.040$	$+^{s}.016$	$+^{s}.025$
No. of Stars ...	196	109	124	141	85
Probable Error ...	$\pm^{s}.064$	$\pm^{s}.057$	$\pm^{s}.051$	$\pm^{s}.046$	$\pm^{s}.041$

Mean values ... H. = $+^{s}.479$ A.C. = $+^{s}.083$ B. = $+^{s}.027$.

The relative smallness of the values for H. and B. in 1893, and for H. and A. C. in 1895, I am inclined to attribute to the

failure of automatic registration mentioned above. With these exceptions there is no large annual variation, and, in fact, nothing that might not be accidental owing to some of the causes explained. I have, however, gone further into the subject from three points of view.

(1) Dividing each year into months.
(2) Dividing each day into 3-hour groups.
(3) Grouping the stars for every 10° of N.P.D.

The first of these is done for B. and H., the others for B. only, as there seemed to be insufficient data for a complete discussion of all three.

	H.			B.		
	Two-Method P.E.	No. of Stars.	Probable Error.	P.E.	No. of Stars.	Probable Error.
	s		s	s		s
January	+·443	12	±·099	+·034	53	±·055
February	+·425	24	±·090	+·004	44	±·066
March	+·454	30	±·063	+·015	68	±·060
April	+·451	31	±·075	−·021	53	±·053
May	+·456	39	±·081	+·022	69	±·055
June	+·471	26	±·071	+·031	42	±·058
July	+·520	19	±·113	+·040	31	±·051
August	+·455	22	±·062	+·022	66	±·050
September	+·498	17	±·055	+·032	57	±·046
October	+·489	19	±·056	+·021	65	±·055
November	+·500	21	±·076	+·043	77	±·056
December	+·502	22	±·089	+·023	38	±·042

G.M.T.	0^h	3^h	6^h	9^h	12^h	15^h	18^h	21^h
P.E. of B. ...	−^{s}·003	+^{s}·028	+^{s}·006	+^{s}·024	+^{s}·030	+^{s}·037	+^{s}·034	−^{s}·018
No.	3	45	160	166	125	89	48	21
Probable Error	±^{s}·077	±^{s}·062	±^{s}·053	±^{s}·055	±^{s}·059	±^{s}·040	±^{s}·058	±^{s}·055

N.P.D.	51°–61°	61°–71°	71°–81°	81°–91°	91°–101°	101°–111°	111°–121°
P.E. of B. ...	−^{s}·002	+^{s}·033	+^{s}·020	+^{s}·029	+^{s}·019	+^{s}·019	+^{s}·006
No.	56	126	154	155	94	54	17
Probable Error	±^{s}·064	±^{s}·054	±^{s}·050	±^{s}·050	±^{s}·051	±^{s}·061	±^{s}·070

As I anticipated in the early part of the paper the result should be persistently positive, it may be well to note the cases where it is negative, or so small as to be of doubtful sign. I find that a very large proportion of the observations included in B. February, B. April, and B. 6^h were taken in 1893. It has occurred to me to reject 1893, but the evidence is insufficient as to whether on any occasion the registration of signals was or was not automatic. So I have allowed it to stand.

The cases B. 0^h, B. 21^h, and B. 111°–121° rest upon very few observations, and probably do not give a real mean value at *all*.

There remains only B. 51°–61°, but I find that a very unfair proportion of these are of *a Lyræ*, which brings me to another line of investigation.

It is said that there is an almost invariable tendency to observe (galvanically) bright stars relatively earlier than faint ones, possibly owing to a larger bisection error which may be systematic. Into this question, however, I have no wish at present to intrude, as it does not come within the scope of the paper. I only allude to it because if true the anomalous nature of the result, B. 51°–61°, might be fairly ascribed to the supposition that for *a Lyræ* in particular the galvanic time was early and hence the relative P.E. too small.

I should have been glad to carry out the comparison between groups of stars of different magnitudes; but there is practically no reliable evidence as to the observing conditions in each case, and as to the relative brightness of the same star under different conditions of daylight, twilight, darkness, and cloud.

One other field remains, not foreign to the subject. In observing slow-moving stars, I have practically no data to go upon, but, so far as my experience goes, stars right up to the pole should not give more widely different results between the two methods than the clock-stars for which the data are at hand.

For stars within a few degrees of the pole, I am inclined to think that the Greenwich method of galvanic observations with the very slight modification necessary to make it applicable to eye-and-ear observations, by substituting a known second from the clock for the galvanic contact simultaneously with which the bisection is made by means of the Right Ascension micrometer, would give practically the same result by either method.

A Note on the Result concerning Diffraction Phenomena recently criticised by Mr. Newall. By F. L. O. Wadsworth.

(*Communicated by the Secretaries.*)

In the November number of the *Monthly Notices* Mr. Newall has a note calling attention to an error in a result recently used by me in developing the theory of the "contrasting" or "delineating power" of telescopes. A criticism of this same result had already been published by Professor Schaeberle in the *Astronomical Journal* (No. 421). The criticisms of both Mr. Newall and Professor Schaeberle are just so far as the inaccuracy of the result alone is concerned; but they are both at fault as to the real error that was committed in obtaining it, and as to its influence on the conclusions of my former papers.

This error was discovered by me several days before I had seen either Mr. Newall's or Professor Schaeberle's article.* A note has been published in the *Astronomical Journal* (No. 424) pointing out the errors in Professor Schaeberle's criticisms; in the present communication I wish to point out other errors in certain statements by Mr. Newall.

A. At the beginning of his note Mr. Newall refers to certain papers of mine in a way that leads one to infer (1) that they were merely duplicate publications in different journals; (2) that the conclusions of all these papers were affected by the error in the expression for I^2_{111}, the focal plane illumination due to the light from the sky. The first point is not perhaps an important one, but I should like to say a few words in regard to it. My preliminary note in the *Monthly Notices* (1897 June, pp. 586–9) simply pointed out two facts whose importance, in photographic work at least, had not, apparently, been fully recognised—*i.e.* that the general illumination of the sky, due to the scattering of light by small particles in our atmosphere, is (*a*) of much greater importance in photographic than in visual work, because the intensity of the scattered light varies inversely as the fourth power of the wave length; (*b*) that this illumination can be considered as equivalent to an infinitely extended uniformly luminous area; and that it is the *contrast* between the general illumination of the focal field due to such an area and the intensity of the image of any object, rather than the absolute value of the latter quantity, that determines the "visibility" and to a large extent the "definition" (both visual and photographic) of faint objects. In that note I also gave, without proof, some of the conclusions which I had then reached in the development of this general theory of "contrast" and "delineating power," based on these and other results. The next publication referred to was that in the *Astrophysical Journal* (1897 August, pp. 119–35), in which the general preliminary development of this theory was taken up from a purely analytical side. It was intended to make use of the results obtained, in conjunction with those derived from the well-known theory of "resolving power," in a discussion of the best practical instrumental conditions of working in the following special cases:—

(*a*) Nebular and stellar photography.
(*b*) Nebular and stellar spectrography.
(*c*) Coronal photography during and without an eclipse.
(*d*) Photography of solar, lunar, and planetary surfaces.
(*e*) Meteor photography and spectrography.
(*f*) Visual observations of fine markings on lunar and planetary surfaces.
(*g*) Visual observations of faint comets, nebulæ, the Gegenschein, zodiacal light, &c.

* *Astrophysical Journal*, 1897 December, p. 463; ibid. 1898 January, p. 77.

(*h*) Measurements of angular diameters and distances with the micrometer, heliometer and interferometer.

In each of these cases the conditions of working differ to a considerable degree; and although much has been written on each, there still seemed to be some points that called for further discussion. (*a*) was discussed in the *Astronomische Nachrichten* (No. 3439) (this paper was afterwards published in *Knowledge*); (*d*) in the *Observatory* (1897 September, October, and November, pp. 303, 365, 404); and (*f*) in the *Astronomical Journal* (No. 414); the remaining cases have not yet been taken up in detail. These papers are not therefore duplicate publications, as intimated by Mr. Newall.*

B. With reference to point (2) Mr. Newall states that my conclusions "concerning the performance of various lenses" are based "on the misinterpretation of a result obtained by Stokes," and that consequently my "conclusions are incorrect," and my "criticism and attempted explanation . . . of practical results obtained with large and small reflectors and refractors falls to the ground." These statements again are incorrect. In the first place, the result to which Mr. Newall refers (the expression for I^2_{111}) *was not obtained by Stokes* (although he gave an analytical proof of the value of the integral involved), but by Lord Rayleigh, who announced it (for the first time, I believe), in his memoir on the Wave Theory in the ninth edition of the *Enc. Brit.*, as follows :—"If we integrate (30)—*i.e.*

$$d\xi \int_{-\infty}^{+\infty} I^2 d\eta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

with respect to ξ, between the limits $+\infty$ and $-\infty$, we obtain πR^2, as has already been remarked. This represents the whole illumination over the focal plane, due to a radiant point whose image is at O,† *or reciprocally the illumination at* O (*the same as*

* The practice of publishing a paper simultaneously in several journals is one that is quite common on this side of the water. Personally, I have followed it only a few times (three altogether, including the recent case in *Knowledge*[1]); but I do not consider it necessary or in good taste to either defend or condemn it. It should be said, however, that the reason for it, when it is done, is not that usually imputed to us by our transatlantic friends, but is simply the desire to reach our co-workers in the same field in this country. There are very few of our institutions which have even *one* complete file of the leading scientific publications in any subject; not a single one, as far as my experience goes, that has complete files of *all*. Many munificent gifts have been made for buildings and large instruments, but the fact has not yet impressed itself upon either the American public or upon our Boards of Trustees, that in order to carry on the work of an institution effectively, a good library and equipment of minor instruments is quite as important and essential, if not more so, than a fine building and (for example) a big telescope.

† O is the centre of the field.

[1] In a number of cases my papers have been *reprinted* in other journals. This is quite a different case, and one in which the editors of the journals are solely responsible and solely concerned.

at any other point), due to an infinitely extended luminous area."* A corresponding result is reached earlier in the same memoir for the intensity of illumination in the image of a long line.*

In the second place, the conclusions in my different papers are based not upon this one result, but, as already pointed out, upon the indications of the general theory of "contrast" or "delineating" power. In two of the three cases, *i.e.* (d) and (f), that have so far been considered, the result does not enter *at all*, and Mr. Newall has not therefore any right whatever to refer to these cases as affected by the error in the expression for $I^2{}_{111}$. The only case (yet considered) in which it does enter is (a). The conclusions reached in this case would have been erroneous had it not been for the fact that in reaching them I omitted (fortunately or unfortunately) to consider the effect of atmospheric aberration on the *effective intensity of point and small surface areas during prolonged photographic exposures.* This effect had not been lost sight of, but its importance in (a) was at first under-estimated. It was intended to take up at once the general investigation of this effect as Part II. of the "General Theory of Telescopic Images" (of which Part I. was published in the *Astrophysical Journal* 1897 August), but the investigation had to be temporarily laid aside.† When I did recently take it up again, I at once discovered that the effect of this factor *in prolonged photographic exposures* would be in general to diminish the *effective photographic intensity* of *faint* point and small surface sources (stars, stellar nebulæ, &c.) in the ratio $\frac{1}{f^2}$, and of line sources in the ratio $\frac{1}{f}$.‡ If the result for $I^2{}_{111}$ had been (as first assumed) independent of f, the contrast would therefore have varied as $\frac{1}{f^4}$ or $\frac{1}{f^3}$, instead of $\frac{1}{f^2}$, as found in practice. This discrepancy led me to reinvestigate Rayleigh's result and discover the error in the value for $I^2{}_{111}$. As it now turns out, the expressions for the *effective photographic contrast* between sky and faint stars, or faint diffused nebulæ, are practically correct as given in my preceding papers; the omission of the factor $\frac{1}{f^2}$ in the denominator (expressing the intensity of illumination due to the sky) just balancing the omission of the factor

* "Wave Theory," *Enc. Brit.* vol. xxiv. §§11 and 12. A reference to these paragraphs was given in both my preliminary note to the *R.A.S.* (*Monthly Notices*, footnote on p. 587) and in my subsequent paper in the *Astrophysical Journal* (footnotes on pp. 130, 133). I can hardly see how these could have so completely escaped Mr. Newall's attention. He has indeed completely overlooked the error in the expression for the intensity in the image of a long luminous *line*, although it is exactly of the same nature as that for an extended luminous *area*.

† See note in *Astrophysical Journal*, 1898 January, p. 78.

‡ For further discussion of this point see Part II. of "General Theory of Telescopic Images; Effect of Atmospheric Aberration," *Astrophysical Journal*, 1898 January, p. 70.

$\frac{1}{f^2}$ in the numerator (expressing the effect due to atmospheric aberration). The main conclusions of the paper on stellar and nebular photography, (*a*), are therefore correct, as well as those on planetary observations, (*d*) and (*f*); *i.e.* at least so far as the theory upon which they are founded (and this has not as yet been questioned as far as I know) is correct. As regards this latter point it seems to me that the agreement between the actual times of exposure required to obtain a given photographic effect with different lenses (Barnard's and Pickering's results), and the computed times as determined by the theory of contrast, is too remarkable and striking to be considered as simply accidental and fortuitous.*

There is one minor conclusion of the paper in the *Astronomische Nachrichten* which is indeed based directly and solely upon the first (erroneous) expression for I^2_{111}, and which is consequently in error. This is the conclusion in regard to the "fogging" of the photographic plate by the sky illumination, and the consequent relation between the times of exposure possible with lenses of different apertures.†

Finally, just a word as to the actual error which was committed in obtaining the value of I^2_{111}, since this has not been pointed out by Mr. Newall. In the case of Lord Rayleigh the error was (apparently) due to the assumption (without proof) of the general principle of reciprocality or reversibility of images, *i.e.* that (as stated in my paper in the *Monthly Notices*)

$$\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} I^2 d\xi d\eta \;.\equiv.\; \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} I^2 dx dy \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

In my case (I approached the question from a somewhat different point of view) the error was a more purely analytical and hence, in many respects, a less excusable one. Mr. Newall is correct in saying "there is a discontinuity in my solutions." In the paper in the *Astrophysical Journal* I derived three expressions—(13), (16), (17)—for the most general case of an image of a source having any form, extent, or distribution in intensity. I applied the first of these—(13)—to the determination of the correct expressions for the intensity in the images of short lines and small uniformly luminous circular areas.‡ Further, when (13) was applied to the cases of a long line and an infinitely extended source, I also obtained correct expressions [(19) and (31)], but

* See *Ast. Nach.* No. 3439, § 100; *Knowledge*, 1897 August, p. 194.

† A note calling attention to this error has been sent to the *Astronomische Nachrichten*. I may perhaps point out in this connection that this result was not regarded as a particularly important one, and was not therefore included in the summary of conclusions at the end of the paper. I said in regard to it, "the mere ability to lengthen the time of exposure (at least beyond twenty-four hours) by decreasing the size of the objective would not in itself be of great importance."

‡ These results were those used in the discussion of cases (*d*) and (*f*).

I assumed that these expressions (in which the variables of integration were x and y, and the field of integration the radiating source) became identical [see (1) above] with the corresponding ones [(8) and (30)]* used by Rayleigh (in which the variables of integration are ξ, η, and the field of integration the focal plane). This would be the case when the limits of integration are infinite, if (as at first appears) the variables x, y were *symmetrically* involved with the variables ξ, η, in the expression for $I^2{}_1$. An inspection of (14) (of my paper), which expresses the value of r (the variable in I^2) in terms of x, y, ξ, η, shows that this is not the case. The first two variables are each multiplied by a factor of dissymmetry, $\frac{f}{D}$, and in order to obtain two new variables symmetrically involved with ξ, η, we must substitute

$$x = \frac{D}{f} d\xi_1, \qquad y = \frac{D}{f} d\eta_1,$$

which gives us in (19) and (31) respectively,

$$\int_{-\infty}^{+\infty} I^2 dy = \frac{D}{f} \int_{-\infty}^{+\infty} I^2 d\eta_1 = \frac{D}{f}(z_{,,}) \quad . \quad . \quad . \quad . \quad . \quad . \quad (19a)$$

and

$$\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} I^2 dx dy = \frac{D^2}{f^2}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} I^2 d\xi_1 d\eta_1 = \frac{D^2}{f^2}(z_{,,,}) \quad . \quad . \quad . \quad (31a)$$

and the integrals [$(z_{,,})$ and $(z_{,,,})$] of *these last expressions* become respectively identical with the integrals (8) and (30) of Lord Rayleigh.

Yerkes Observatory: 1897 *December* 24.

The Concave Grating for Stellar Photography. By Charles Lane Poor and S. Alfred Mitchell.

(*Communicated by Dr. C. L. Poor.*)

The concave grating has proved a most powerful instrument for spectroscopic research, but heretofore it has not been successfully applied to stellar spectroscopy. Experiments are now being carried out at the Johns Hopkins University, under the direction of Dr. Charles Lane Poor, with the view of thoroughly testing the various methods of using the concave grating for astronomical purposes. The methods, originally suggested by Professor Rowland, were developed and the formulas derived by Dr. Poor, and the apparatus constructed under his direction; the photographs were made by Mr. S. Alfred Mitchell.

* "Wave Theory," *Enc. Brit.* §§ 11 and 12.

There are two radically different methods of using the concave grating for stellar work :

First, in connection with an objective ; the grating merely replacing the ordinary stellar spectroscope. This was tried by Professor Crew at the Lick Observatory in 1892 and a few results obtained.

Second, direct ; the grating is the objective and the spectroscope combined : the light from the star being reflected directly from the grating to the photographic plate. This method was first developed by Dr. Poor in 1892, when a few experiments were made. No definite results were then obtained, however. Experiments were resumed in October last, and some promising photographs have since been obtained.

This paper is confined to an explanation of the second method, to the derivation of the necessary formulas, and to a few notes in regard to the photographs already taken.

From the theory of the concave grating we have the general equation,

$$r = \frac{R \rho \cos^2 \mu}{R (\cos \mu + \cos \nu) - \rho \cos^2 \nu} \qquad (1)$$

(see Rowland, *American Journal of Science*, vol. xxvi. 1883 Aug.). In this equation ρ is the radius of curvature of the grating, and the axis of the grating is the line of reference for angular measurements. R and ν are the spherical coordinates of the source of light ; r and μ those of the curve on which the spectra are brought to a focus.

This equation may be put into the following form :

$$r = \frac{\rho \cos^2 \mu}{\cos \mu + \cos \nu - \frac{\rho}{R} \cos^2 \nu} \qquad (2)$$

If now the source of light is at an infinite distance, R is infinite, and the equation reduces to

$$r = \frac{\rho \cos^2 \mu}{\cos \mu + \cos \nu} \qquad (3)$$

This is the general equation for the case under consideration.

We may use the grating in a number of different ways, depending upon the position of the photographic plate, and of the source of light in reference to the axis of the grating. One position is by far the best for photographic work, and in this note the formulas for that case alone are given. This position is that in which the centre of the photographic plate is on the axis of the grating.

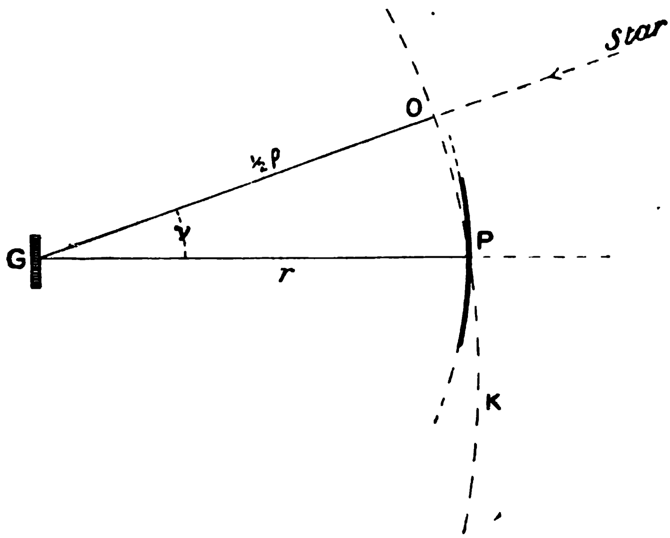
To investigate this case fully, return to the general equation, (3). For a fixed value of ν all the spectra are brought to a focus on the curve,

$$r = \frac{\rho \cos^2 \mu}{\cos \mu + \cos \nu}$$

in which $\cos\nu$ is constant. When μ is so small that its cosine may be taken as unity, this equation reduces to

$$r_0 = \frac{\rho}{1+\cos\nu} = \text{a constant,}$$

and the focal curve becomes a circle. This case is shown in the following figure, in which G is the grating and P the photographic plate.



The light from the star comes in in the direction of OG. The curve, OPK, is a parabola, OG being the half-parameter and equal to $\frac{1}{2}\rho$. For a constant value of ν, those spectral lines on the photographic plate, for which $\cos\mu$ can be assumed equal to unity, are brought to a focus on a circle whose radius is r. When the dispersion is large, so that $\cos\mu$ must be taken into account, the focal curve is as defined by equation (3), and the photographic plate must be bent along this curve.

By the theory of diffraction (Rayleigh, *Encyc. Brit.*, "Wave Theory of Light")

$$\lambda = \frac{\omega}{N}(\sin\nu + \sin\mu) \tag{4}$$

where ω is the grating space and N is the order of the spectrum. From this we have at once

$$\frac{d\lambda}{d\mu} = \frac{\omega}{N}\cos\mu$$

To find the change in wave length as we pass along the focal curve, we have

$$\frac{d\lambda}{ds} = \frac{d\lambda}{d\mu} \cdot \frac{d\mu}{ds}$$

and

$$\frac{d\mu}{ds} = \frac{1}{\sqrt{r^2 + \left(\frac{dr}{d\mu}\right)^2}}.$$

Differentiating the equation of the focal curve, we find

$$\frac{dr}{d\mu} = \frac{r \sin\mu - \rho \sin 2\mu}{\cos\mu + \cos\nu} \equiv \phi(\mu) \tag{6}$$

Whence substituting, we finally find

$$\frac{d\lambda}{ds} = \frac{\omega}{\mathrm{N}} \cdot \frac{\cos\mu}{\sqrt{r^2 + [\phi(\mu)]^2}} \tag{7}$$

and this is the general formula for the change in wave length along the focal curve.

If, in this equation, we put $\mu = 0$, it reduces to—

$$\frac{d\lambda}{ds} = \frac{\omega}{\mathrm{N}} \cdot \frac{1}{r_0} \tag{8}$$

a constant. Hence at this point the spectrum is "normal." Within the limits, therefore, in which we can take $\cos\mu$ as equal to unity, the spectrum may be considered as normal.

For a grating of medium dispersion an entire spectrum will be practically normal, provided that the centre of the plate is on the axis of the grating—*i.e.* μ equal to zero for the middle of the spectrum. In the grating used in our experiments the entire first order spectrum subtends an angle of less than 6°. By computation we find from the above formulas that the scales of different portions of the spectrum differ by less than three parts in a thousand. The advantages of this method of working are thus apparent.

In order to test the above method, a small Rowland concave grating with a ruled surface of 1 × 2 inches was used. The grating has a radius of curvature of one metre, and is ruled with 15,000 lines to the inch. The apparatus for mounting the grating is extremely simple, consisting of a light box clamped to the tube of the equatorial—the telescope being used merely as a finder. The light from the star falls directly on the grating, is diffracted and brought to a focus on the photographic plate. The grating is mounted in an ordinary holder, which can be adjusted by side and back screws. The plate-holder holds a plate 1 × 5 inches, bent as closely as possible to the proper curve. The holder is capable of adjustments, so that the plate and the grating can be made parallel. The box is clamped to the telescope in such a way that the lines of the grating are parallel to

the equator; and accordingly, by regulating the driving clock of the telescope to run a little too slow or too fast, the spectrum can be made of any convenient width.

For our trials *Sirius* was the star principally used, and the exposures ranged from ten minutes to one hour, according to the width of the spectrum. All the photographs were made with the first order spectrum, and Seed's gilt-edge plates were used. The spectra are about 5 cm. long, and vary in width from 0·1 mm. to 1·5 mm., depending upon the exposure and the rate of the clock. Details of a few specimen plates follow:

Sirius.—November 27. Exposure 40 minutes; width of spectrum, 1·5 mm. Plate shows eight hydrogen and H and K lines.

Capella.—December 9. Exposure 40 minutes; width of spectrum, 0·2 mm. Plate shows F, G, *h*, H, K, and about fifty fine lines.

Procyon.—December 15. Exposure 40 minutes; width of spectrum, 0·15 mm. Plate shows six hydrogen, H, K, and about twenty fine lines.

Rigel.—December 28. Exposure 85 minutes; width of spectrum, 0·1 mm. Plate shows fourteen hydrogen, H, K, and six other lines.

Sirius.—January 3. Exposure 40 minutes; width of spectrum, 0·1 mm. Plate shows sixteen hydrogen, H, K, and fifteen other lines.

The glass positive which accompanies this paper is the enlargement of two of our negatives of the spectrum of *Sirius*. The lower one is the enlargement of a plate taken 1897 December 15; the upper spectrum is the enlargement of the plate taken 1898 January 3 (see above). Since our original negatives are extremely narrow, considerable trouble was experienced in widening out the spectra without introducing spurious lines. Although some of the finer lines in the enlargement are undoubtedly spurious, yet the plate shows the general character of our photographs, in that it shows clearly the hydrogen lines, K, and many other lines which can be easily identified.

All these experiments were carried out in the Observatory, which is most unfavourably situated for such work. We are confident that much better results will be obtained under better conditions, and think that this method promises to become of great value to stellar spectroscopy.

Johns Hopkins University:
1898 *February* 5.

On a Convenient Method of adjusting a Polar Axis to the Diurnal Motion. By David P. Todd.

[*Communicated by the Secretaries.*]

To eclipse observers often occurs the practical problem of adjusting a polar axis to diurnal motion in the briefest possible time. As a rule their mountings will have no circles, or very small ones; so that the usual method of adjustment either is inapplicable or falls short of the precise alignment desired. Besides this, the finally adjusted axis points in the direction of the true pole, whereas, for best following by clock-motion, it should point toward the apparent or refracted pole, as indicated by Mr. Davidson in his recent paper.

Some years ago, when equipping the U.S. expedition to West Africa for the eclipse of 1889 December 22, I hit upon a method of speedy adjustment which has not, I think, been described heretofore, and which others may find as convenient and expeditious as I have repeatedly since that time. The mechanical requisite is a simple one; the astronomical requisite is that the poleward horizon must be unobstructed—close circumpolars at least must be visible.

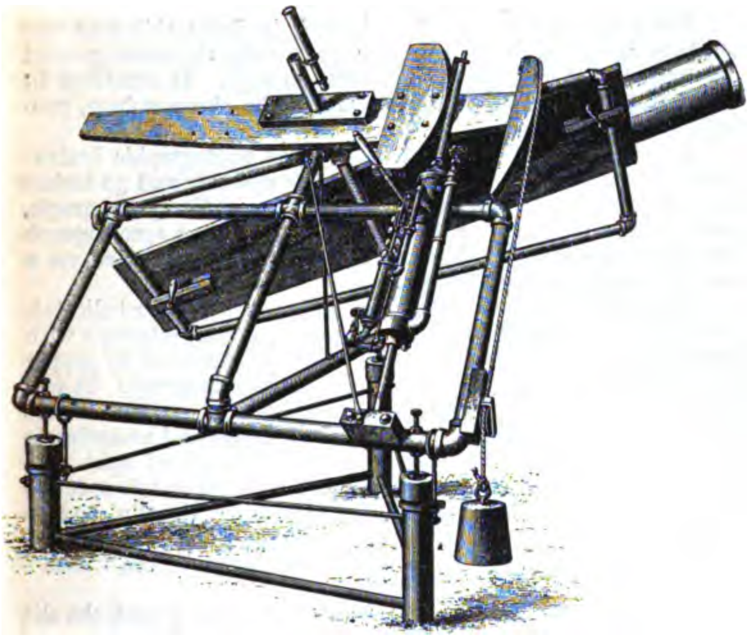
It so happened that this latter precluded actual use of this method on the expedition in question; for, obliged as we were to locate in low south latitudes, proximity of a slight southerly eminence cut off our poleward view. But in the expedition to Japan in 1896—provided by the liberality of Mr. D. Willis James, a trustee, and his son Arthur Curtiss James, a graduate of Amherst College—the method was adapted to three equatorial mountings with perfect success. A lesser one is shown in the accompanying figure.

At the upper or left-hand end of the polar axis is shown a small finder, rigidly attached. The axis of it is adjusted parallel to the mechanical axis of rotation of the polar axis in its bearings. This is easily done by collimating on a well-defined object so distant that twice the space between telescope and polar axis is not a considerable part of distance of object itself.

The finder's large field shows an annular reticle, the ring's angular radius being equal to the polar distance of *Polaris*, if the mounting is to be adjusted in the northern hemisphere. Periphery of the ring is graduated counter-clockwise to twenty-four hours. I found by several trials that graduation to subdivisions of five minutes was fine enough. Preparation of those reticles was troublesome and expensive at first, because done with a dividing engine on glass. At last I found they could be made with high accuracy by photography for a few pence each: carefully draft the circle, graduation, and numerals on Bristol board in very fine lines, and reduce photographically, as if a lantern

transparency. The thinnest of cover glass was used; also the wet collodion process, because it yields a plate almost absolutely transparent.

The finder's focal length must be measured accurately, and the photographic reduction suited thereto. Then adjust the horizontal line of the reticle (18^h–6^h) parallel to the horizontal arm attached to the polar axis. See that this remains level by any convenient means, while the three adjusting screws under the mounting quickly bring *Polaris* into that part of the field



marked by its hour-angle on the graduated circle. A few moments' trial suffices for this adjustment; and verification at sight is always possible whenever the pole star is visible, the only requisite being a knowledge of sidereal time. In some cases a diagonal eyepiece will be an additional convenience. For the southern hemisphere a larger telescope is necessary, but a smaller field will suffice.

After practical use I find this method of adjusting a polar axis most convenient and desirable for expedition work, where disturbance after first adjustment is likely to occur. An accidental thrust in putting an instrument upon the mounting, or some unintentional blow from a rough labourer, may disturb a mounting so that readjustment is necessary. And the means of

constantly testing and quickly remedying this cardinal element of polar alignment is a great comfort as the hour of totality approaches, when a hundred other details crowd for instant attention.

Note on some Results obtained with a Small Prismatic Camera at the Eclipse Camp at Talni. By J. Evershed.

The eclipse work which I undertook in India this year was entirely spectroscopic, and covered practically the same ground as that which I attempted in Norway in 1896. It consisted in obtaining photographs of the spectra of the chromosphere, prominences, and corona.

For this purpose I constructed three photographic instruments: a prismatic camera of 2¼ inches aperture and 36 inches focal length, fitted with two 60° prisms; a slit spectrograph, containing two quartz prisms; and a large slitless spectrograph attached to a 6-inch telescope, the latter being mounted on a roughly made equatorial stand.

In addition to these I had available a 4-inch polar heliostat, kindly lent by Mr. Maw, and a 3½-inch equatorial telescope with solar spectroscope attached. The heliostat was used to supply light to the prismatic camera and the slit spectrograph. It was of the ordinary form with two mirrors, but was modified to suit the special work by removing the second mirror and mounting it in the same plane as the first, so that two beams of light were available instead of one beam twice reflected. The tele-spectroscope was used to observe the reversing layer visually, and to determine the right moment to expose the prismatic camera and large slitless spectrograph in order to photograph the "flash" spectrum.

I obtained thirteen photographs in all: one only with the slit spectrograph, which was exposed during the whole time of totality; two with the slitless spectrograph—one at the beginning and one at the end of totality; and a series of ten with the prismatic camera, beginning about 20 seconds before second contact and ending about the same interval after third contact.

The single photograph obtained with the slit spectrograph shows no details of any kind on the very faint continuous spectrum of the corona. The large slitless spectrograph yielded two fairly good negatives, which show a considerable number of bright lines in the region of the spectrum between F and H. The best results were, however, obtained with the prismatic camera. This instrument gave images of the spectrum extending from λ 6000 in the orange to λ 3380 in the ultra-violet. Unfortunately the scale is very small; it is only ·33 inch to the Moon's diameter, and in length 1·52 inches from D to H, the total length of the spectrum photo-

graphed being 2·9 inches. Notwithstanding this, however, a large amount of detail is visible on some of the plates, and the definition is excellent in the ultra-violet region.

The first two photographs of the prismatic camera series were exposed at about 20 seconds and 12 seconds before totality respectively. At these times the last remaining thread of sunlight had narrowed down to a width of 8″ for the first and about 4″ for the second exposure, at the widest part of the cusp, and, acting as a fine slit, gave excellent spectral images. Accordingly, the photographs show the ordinary Fraunhofer spectrum very finely, but the lines are much less dark than in the ordinary solar spectrum; the F line in particular seems to be almost obliterated by the bright chromosphere radiation. H and K, and all the hydrogen lines except C, are represented in the photographs by bright arcs extending on each side of the continuous spectrum, and numerous other short bright arcs can be made out in the ultra-violet.

The next plate (No. 3) was exposed about 2 seconds before the last remnant of photosphere vanished, and was allowed to remain exposed for about 4 seconds. Just before making this exposure I removed the slit of the visual spectroscope and watched the narrowing cusp-spectrum in the region near *b* without any slit, beginning to observe not more than 10 seconds before totality.

At first I could see the Fraunhofer dark line spectrum very clearly, just as though the circular slit ordinarily used in observing the prominences was still in place. The continuous spectrum rapidly decreased in width, and then, instead of narrowing down to a single thread of light, as I had expected, it suddenly began to break up into a number of narrow bands, between which the bright lines flashed out in the most astonishing way, extending in long arcs over thirty degrees or more of the limb. I then made the exposure.

In the photograph only the stronger lines in the part of the spectrum observed have been impressed. In the ultra-violet, however, the spectrum is thickly crowded with bright lines. In this region the lines seem to be intrinsically more intense than in the lower spectrum, whilst the continuous spectrum of the photosphere is relatively feeble. All the bright lines throughout the spectrum, excepting those due to the chromosphere proper, form a well-defined band of uniform width running the whole length of the spectrum. The length of the arcs, or width of the band of bright lines, corresponds to an arc of over 40 degrees of the Sun's limb, and this implies a depth not exceeding 1″·5 for the gases composing the reversing layer.* The extreme thinness of the layer is evidenced also by the well-defined dark bands running lengthwise from end to end of the spectrum, and interrupting all

* Assuming the Moon's apparent semi-diameter = 997″·0, and the Sun's = 974″·9.

the bright lines of the flash spectrum. These are due to the projecting lunar mountains, which had already in places occulted the reversing layer, even before the eclipse was quite total.

Plate No. 4 was given an instantaneous exposure a few seconds after totality had commenced. It shows simply the ordinary chromosphere spectrum; but there is a curious feature in the prominence spectrum which is well brought out in this photograph. In the extreme ultra-violet most of the prominences give an apparently continuous spectrum. This appears to commence abruptly at about λ 3660, at the point where the hydrogen series ends, and it extends in an unbroken line to the end of the plate, at about λ 3390.

Of the remaining photographs of the series, Nos. 7, 8, and 10 are the most interesting. No. 7 was given an exposure of about 30 seconds, ending just before third contact; the corona line and many of the flash spectrum lines are clearly shown; they are crossed by narrow streaks of faint continuous spectrum. The distribution of the "1474" light seems to conform in a general way to the structure of the corona; but it is much stronger on the east limb than on the west, where it is scarcely traceable. In this photograph the entire series of hydrogen lines are shown, including *a*.

No. 8 was exposed at the moment when the photosphere broke out, and a large number of the flash spectrum lines are shown between the streaks of continuous spectrum. The focus is, however, not so good as in No. 3.

No. 10, which was exposed about 18 seconds after totality was over, is remarkable for the fringe of bright lines bordering the continuous spectrum in the ultra-violet, where, apparently, *every* dark line of the Fraunhofer spectrum ends in a short bright line.

With regard to the question of the relation between the bright lines of the flash spectrum and the dark lines of the Fraunhofer spectrum, it would be exceedingly rash to draw any definite conclusions from these negatives, pending the discussion of the magnificent results obtained by Sir Norman Lockyer and others. It may be stated, however, as the result of a preliminary examination of the plates, that while the flash spectrum cannot be regarded as the exact converse of the Fraunhofer spectrum, yet the correspondence between the two is a sufficiently striking one, and from it one might infer that the majority of the dark lines in the solar spectrum are really due to absorption in the reversing stratum.

But in studying the flash spectrum it is very necessary to bear in mind that, although apparently very shallow, the reversing layer is really something like 800 miles in depth, with probably an enormous increase of density near the base, or, rather, in the region where the photospheric clouds are precipitating.

Under such conditions the main part of the absorption producing the Fraunhofer spectrum probably takes place within a

few miles only of the photospheric clouds. (It does not seem necessary to suppose it to take place within or between the clouds, although this may, of course, be the case to some extent.)

The flash spectrum, however, as we see it, represents the higher part of the stratum, which is not nearly so effective in producing absorption, on account of the much lower density; and if the various gases concerned are not uniformly distributed throughout the layer, the relatively shallow but dense stratum at the base may contain gases which are not present in the region above, and *vice versâ*.

On this view, helium and other gases having prominent lines in the flash spectrum, which are only feebly represented, or are not present at all, in the Fraunhofer spectrum, are gases which exist only in the upper regions of low density. It is not necessary to suppose that the temperature of these gases is as high as that of the photospheric background, but simply that a ray of light, emitted by the photosphere in its passage outwards, encounters relatively few molecules, notwithstanding that the gases may extend to great elevations in the chromosphere.

It is evident that the strength of a bright line in the chromosphere or flash spectrum depends to a large extent on the height to which the gas producing it extends, and is independent of the density or total quantity of gas overlying the photosphere by which the intensities of the dark lines are mostly determined.

Thus, by assuming a somewhat irregular distribution of the gases in the layer itself, the differences between the Fraunhofer and flash spectra may be accounted for without abandoning the view that the greater part, if not the whole, of the gaseous absorption takes place between the photosphere and the upper limits of the reversing layer.

Note on the Zodiacal Light. By E. Walter Maunder.

The recent eclipse expedition to India gave me the first favourable opportunity for observing the Zodiacal Light. I had seen it on a few occasions in England, but the contrast between the faint glimmer, doubtfully seen on a few rare occasions here, and the broad bright glow, which it was impossible to mistake or overlook, seen on every moonless evening during both the outward and homeward voyage, and during our camp life in India, was so great as to seem to make it a duty to utilise such an opportunity as fully as possible. The observations cover a period of two calendar months—1897 December 22 to 1898 February 22—they are, of course, therefore of but little value as compared with a series of observations carried on continuously throughout the entire course of the year. Nevertheless I thought it worth while to submit them to the Society in the hope that they might call the attention

of observers in tropical stations to an object which has been as yet but little studied, and which demands no instrumental equipment.

The first point which struck me with regard to the Light was its brilliance, so far exceeding anything that I had anticipated. I estimated that the brightest regions of the Light, as seen in the evening, were fully six times as bright as the brightest regions of the Milky Way visible at the same time. The morning branch of the Light seemed to me hardly equal to the evening branch, and it was brought into rivalry with brighter regions of the Milky Way—namely, those in *Sagittarius*, *Crux* and *Argo*. I should incline to place it as about three times as bright as the brightest of these. Again, in the evening the Light made itself evident in the twilight considerably before the Milky Way was able to do so, and as seen at sea its reflexion on the water was much more marked.

The question at once occurred to me, is the Light always as bright as this in these latitudes, or are we being favoured with a specially brilliant display? If the former were the case, it seemed impossible to understand why so few people seem to have remarked it, and why the observations of it by astronomers are so rare and incomplete. I made what inquiry I could on this point and found a conflict of testimony; some observers assuring me that in India, at all events under latitude 20°, the Light was habitually as bright as I had seen it; others were just as positive that it had been unusually distinct at this particular season. My own experience, such as it is, would seem rather to support the latter view. Most assuredly the Light was in no such evidence in 1886 during our eclipse voyage to the West Indies, or I could not have failed to have noticed it. I may note that Father Marc Dechevrens of the Zi-ka-Wai Observatory, failed to observe the evening branch during the months of July to September, in the years 1875 to 1879.

It will, of course, be understood that the entire Light was not of this intensity. The brightest portion of the Light was spindle-shaped—the axis of the spindle being the brightest part, and the light shading off in all directions. But whilst the sides of the spindle were not so diffused as to render it impossible to trace their outlines with a fair amount of exactness, the Light at the point faded away so gradually that it was impossible to set a definite boundary to it there. Roughly speaking, the Light was distinctly brighter than the Milky Way for fully 30° of its length. At perhaps 45° it might be of about the same intensity. After this it degraded very rapidly, and when it crossed the Milky Way between *Taurus* and *Gemini* it was quite overpowered by the latter.

A more precise idea of the brilliance of the Light may be deduced from the fact that the young Moon was seen upon it on January 24 and February 22 without the Light suffering extinction. On both occasions it could be clearly made out. On the following

nights, January 25 and February 23, the increased moonlight was sufficient to overcome it.

Beyond the brighter spindle-shaped light a very faint band of light could be traced in a prolongation of the spindle nearly, if not quite, round the entire sky;—at least it could be so traced at the end of December, for I had no opportunity of observing the morning branch of the Light after January 2. During the three weeks in camp the morning Moon interfered almost continuously with the observations of the eastern Zodiacal Light, and on the homeward voyage, though I rose nearly every morning between four and five o'clock, on no single occasion was the sky clear.

The failure to see the morning branch was the more disappointing as the evening branch appeared to shorten as time went on. On the very first occasion, *i.e.* on the evenings of December 22, 23, and 24, the evening branch was traced as far as ι *Tauri*. On February 21 it was scarcely seen so far—certainly no further, the elongation from the Sun being 164° in the first case, and only 102° in the second. It is possible that the brightness of the Milky Way, which crosses the ecliptic near here, was sufficient to drown the feeble glow of the Zodiacal Light at so great an elongation, and that but for its interruption it might have been traced as far from the Sun in February as in December. It was both broader and brighter in the neighbourhood of the Pleiades on the later occasion than on the earlier. As the observations given below indicate, the "spindle" was shorter and broader, was less oval, when last seen than when seen first.

The morning Light could not be traced quite so close to the Milky Way as the evening branch. *Præsepe* marked the furthest point to which it was followed to any degree of certainty. This on January 2 would correspond to an elongation of 156.°

The brightest portion of the Light showed a delicate but unmistakable colour—a faint pale yellow, with perhaps the slightest inclination to the green rather than to the orange. The contrast between this tint and the steely blue of the Milky Way was only less pronounced than the contrast between the broad areas of diffused luminosity of the Zodiacal Light and granulations of the Galaxy. Yet they had one feature in common. I felt convinced that in the Light as in the Galaxy there were dark lanes and rifts, though in the former these lanes are far more difficult objects, and I was not able to lay down the course of any of them with sufficient accuracy. Two lines of somewhat rapid fading, if not positive dark lanes, were suspected at right angles to the ecliptic near longitudes 16° and 25° respectively.

A feature of the Light which especially caught my attention was that it very nearly swamped the stars of the two streams in *Pisces* which radiate from α *Piscium*. The one stream running in a straight line from α to ρ *Piscium* is very nearly normal to the ecliptic; the other, forming a gentle curve and running from α to γ *Piscium*, crosses the Light at a small angle.

The individual stars in these two streams, though many of them are fully of the fourth magnitude, were yet made out with considerable difficulty, especially those near the axis of the Light. I have had no opportunity of examining this part of the sky again since my return home, but so far as my recollection serves me these and other ecliptic stars in *Aquarius* and *Capricornus* were seen with more difficulty in the clear skies of the Red Sea and India than here at home, owing entirely to the great brilliance of the Light.

Beside the morning and evening branches of the Light, a very faint, vague luminosity was observed night after night from January 12 to January 18, lying between *Pollux*, *Procyon*, and *Præsepe*. It had at first seemed to be like a faint extension of the Milky Way, but on January 18 for the first time a clear interval was made out between the following side of the Milky Way and the preceding edge of this faint light. The Light itself was traced about 2° farther east than *Præsepe*. The centre, therefore, of the light was about longitude 112°. It was, therefore, as nearly as the observations allowed, in opposition to the Sun, and was no doubt what is now known as the "Gegenschein."

Below I give a series of outline points as determined on different occasions. It will be noticed that, so far as they go, they point to the Light being very nearly in the plane of the ecliptic; rather in that plane than in the plane of the Sun's equator. How far a more expanded series of observations would have confirmed this view, of course, I cannot say. The fact that the Light can be traced more than 90° from the Sun (indeed, if the Gegenschein be part of it, to actual opposition with the Sun), clearly proves that some portion of the Light is derived from matter lying outside the Earth's orbit. But by far the greater amount of the Light is concentrated in the spindle-shaped beam, and this although, as already stated, the place of its apex cannot be satisfactorily fixed, does not attain anything like so great an elongation, and it seems to me clear, if the Light were due to a disc of matter extending uninterruptedly outwards from the Sun to a considerable distance beyond the Earth's orbit, that the opposition portion would tend to appear much broader than is actually the case. The evening branch of the Light tapers from a breadth of 15° or 16° near the Sun, to one of 4° or 5° near opposition; and the morning branch is about 20° broad at its nearest observable approach to the Sun, and 4° at its greatest distance from it. But the particles between the Earth and the Sun must be "new," that is, invisible, whilst those either in opposition to the Sun, or on the further side of it, are "full." The fully illuminated particles are therefore much nearer to us in opposition, and consequently spread over a greater area, than those nearer superior conjunction, and if the Light were due simply to a continuous disc of particles extending outward from the Sun beyond the Earth's orbit, the portion of it opposite the Sun should be the broadest, not the narrowest.

On the other hand, if we suppose that such a disc of particles lies wholly within the Earth's orbit, its boundary extending say to 0·94 (corresponding to an elongation of 70°) of the Earth's mean distance from the Sun, we should have a glow of much the appearance and character of the brightest part of the Light, the "spindle-shaped" beam, the "Stronger Light" of Jones. The faint, narrow prolongation of the Light seen beyond an elongation of 70°, and traced even to opposition, showing as it does little variation in breadth, would seem to point to a flat ring of matter lying a good way outside the Earth's orbit. A satellite of *Saturn* revolving round its primary in the middle of the Cassinian division of the rings, would offer some analogy to the position of the Earth with regard to the two divisions of the Zodiacal Light.

When the region of the *Pleiades* is approached it seems very difficult to differentiate between the actual Light and faint, indistinct patches and arms of luminosity, which seem to be connected with and to radiate from the *Galaxy*.

But by far the brightest portion of the Light is satisfactorily accounted for by the usual hypothesis of a great disc of finely divided cosmical particles radiating from the Sun.

The plane of the disc seems to me very nearly to coincide with the plane of the ecliptic. The annexed observations made in February show that the Light then lay almost exactly along the ecliptic. The heliographic latitude of the Earth was then 7°·2 S. If, therefore, the disc extends to within a few million miles of our orbit, and if it lie in the plane of the Sun's equator, it should have shown an enormous displacement to the north of the ecliptic, which was most certainly not the case. In fact, the Light appeared if anything to lie further south in February, when the Earth was at its maximum south heliographic latitude, than in December when its latitude was only 3°.

I should like to add that I had read very little on the subject before leaving England, and had therefore not seen Professor Arthur Searle's suggestion for observing the Zodiacal Light by the method of contour lines. I greatly regret this, as the method, though requiring much practice, was obviously the proper one to have adopted.

Evening Zodiacal Light.

(1) *Observations made* 1897 *December* 22, 23, *and* 24.

Northern Border.	Southern Border.
2° N. α Capricorni	ψ Capricorni
ϵ Aquarii	ζ „
μ „	35 Aquarii
β „	3° N. δ „
1° S. γ Aquarii	1° S. ψ^1 „
1° S. η „	1° N. 30 Piscium

Northern Border.	Southern Border.
1° S. γ Piscium	1° S. μ Piscium
ι ,,	Midway between π and α Piscium
ω ,,	
η ,,	ξ Arietis
2° S. γ Arietis	Between 31 and 38 Arietis
Between ζ and δ Arietis	1° N. ε Tauri
1° S. Pleiades	ι ,,

(2) *Observations made* 1898 *January* 15.

β Aquarii	Just N. δ Aquarii
1° S. γ ,,	Just S. ψ^3 ,,
1° S. η ,,	30 Piscium
1° S. γ Piscium	1° N. 20 Ceti
ω ,,	ν Piscium
η ,,	Just N. ε Tauri
ζ Arietis	
Just S. Pleiades.	

(3) *Observations made* 1898 *February* 16, 19, 20 *and* 21.

2° N. γ Piscium	ι Ceti
1° N. ι ,,	6° N. η ,,
3° N. ω ,,	6° N. θ ,,
4° S. γ Pegasi	1° N. α Piscium
1° N. η Piscium	3° N. ξ Tauri
1° S. γ Arietis	Just N. ε ,,
Just N. Pleiades.	

MORNING ZODIACAL LIGHT.

Observations made 1897 *December* 27 *and* 1898 *January* 2.

	ρ Scorpii
1° N. ξ Scorpii	39 Libræ
3° N. β Libræ	1° N 20 Libræ
3° N. δ ,,	4° S. λ Virginis
1° N. μ Virginis	½° S. α ,,
1° N. ζ ,,	3° S. γ ,,
δ ,,	2° S. η ,,
1° S. ο ,,	1° S. β ,,
5° S. β Leonis	Between σ and τ Leonis
1½° S. θ ,,	ρ Leonis
1° N. η ,,	α ,,
γ Cancri	δ Cancri.

The approximate latitudes at the times of observation were :—

1897 Dec. 22	31° 0′ N. Lat.	1898 Jan. 15	20° 45′ N. Lat.
23	31 0	Feb. 16	13 30
24	26 0	19	21 30
28	13 30	20	27 0
1898 Jan. 2	18 0	21	29 0

Mean areas and heliographic latitudes of Sun-spots in the year 1896, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lviii. p. 40, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1896; and Table II. gives the same particulars for the entire year 1896 and the seven preceding years for the sake of comparison. The areas are given in two forms. First, projected areas—that is to say, as seen and measured on the photographs, these being expressed in millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1896 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area for spots north and for spots south of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results from 1889 to 1895 being added, as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888 on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (*Observations of Solar Spots made at Redhill*, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the

Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

The principal features of the record for 1896 are :—

(1) The decrease in mean daily spotted area which began in 1894 has continued at an increasing rate.
(2) The decrease in the umbræ is also maintained. As compared with 1895 there is a diminution of 47 per cent.
(3) The faculæ which had shown a revival in 1895 have diminished, and are now less than in 1894.
(4) The decline in spots is far greater in the northern hemisphere than in the southern.
(5) Consequently, the predominance has passed back to the southern hemisphere.
(6) There has again been little change in the distribution of spots in heliographic latitude.
(7) No spots were seen on eight days during the year, and no faculæ on seven days.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected Umbræ.	Projected Whole Spots.	Projected Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected Whole Spots.	Corrected Faculæ.
	d							
565	1895 Dec. 23·19	28	166	861	1606	114	631	1812
566	1896 Jan. 19·53	26	82	464	841	66	378	966
567	Feb. 15·87	28	205	1413	1187	149	1022	1426
568	Mar. 14·20	26	130	829	1307	93	584	1556
569	Apr. 10·49	28	39	246	935	30	205	1175
570	May 7·73	27	74	433	827	51	301	938
571	June 3·95	27	191	1126	1014	133	783	1167
572	July 1·14	27	128	773	1407	93	576	1553
573	July 28·36	27	53	289	1124	37	209	1228
574	Aug. 24·58	27	273	1656	1703	187	1195	1879
575	Sept. 20·85	27	64	360	1394	48	290	1508
576	Oct. 18·14	28	219	1104	1438	151	794	1568
577	Nov. 14·44	27	93	494	1426	66	363	1603
578	Dec. 11·75	27	198	1130	1348	132	795	1551

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas. Projected Umbræ.	Projected Whole Spots.	Projected Faculæ.	Corrected for Foreshortening. Umbræ.	Corrected Whole Spots.	Corrected Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877
1895	364	237	1330	2059	169	974	2278
1896	364	127	745	1243	90	543	1410

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	d.			°		°	°	°
565	1895 Dec. 23·19	28	171	13·54	460	12·93	− 5·74	13·09
566	1896 Jan. 19·53	26	99	11·93	278	15·44	− 8·24	14·52
567	Feb. 15·87	28	363	14·85	659	16·00	− 5·04	15·59
568	Mar. 14·20	26	433	15·79	151	15·40	+ 7·71	15·69
569	Apr. 10·49	28	129	15·09	76	13·36	+ 4·55	14·45
570	May 7·73	27	3	17·69	298	11·89	−11·63	11·94
571	June 3·95	27	137	19·56	646	16·94	−10·54	17·40
572	July 1·14	27	102	19·18	474	18·48	−11·80	18·60
573	July 28·36	27	43	12·93	166	17·44	−11·16	16·51
574	Aug. 24·58	27	835	12·99	359	13·53	+ 5·01	13·15
575	Sept. 20·85	27	89	11·59	201	11·98	− 4·74	11·86
576	Oct. 18·14	28	75	6·14	719	12·25	−10·51	11·67
577	Nov. 14·44	27	175	11·80	189	13·90	− 1·55	12·89
578	Dec. 11·75	27	167	6·14	628	9·28	− 6·03	8·62

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
			°		°	°	°
1889	360	5·0	+ 7·26	73·0	−11·90	−10·68	11·61
1890	361	53·1	+22·20	46·3	−21·75	+ 1·73	21·99
1891	363	401	+20·49	169	−19·91	+ 8·52	20·31
1892	362	607	+15·09	607	−21·69	− 3·29	18·39
1893	360	517	+14·91	941	−14·26	− 3·93	14·49
1894	364	543	+12·31	739	−15·56	− 3·75	14·18
1895	364	565	+14·26	409	−12·54	+ 3·01	13·54
1896	364	203	+13·60	340	−14·77	− 4·15	14·33

Notes on the Rotation Period of Venus. By E. M. Antoniadi.

(*Communicated by Capt. W. Noble.*)

The question of the rotation period of *Venus* is one to which the reply has eluded many a distinguished astronomer. Nor is the reason of the failures far to seek. The determination is in itself impossible by ordinary visual methods on account of the formidable diffusion of light by the planet's atmosphere, and until the day arrives when the Doppler-Fizeau principle can be successfully applied to the limb of *Venus*, we may justly display scepticism as to the value of current rotation periods.

The first attempt to determine the rotation period was made by Dominique Cassini in 1666–1667. Cassini considered the spots to be animated by a motion either of libration or rotation, having a period of less than 24 *hours*, round an axis almost coinciding with the plane of the planet's orbit.

Bianchini, who affirms that he had seen *Venus* rotate (1726–1728), fixed the rotation period as 24 *days* 8 *hours*. The axis, he considered, formed an angle of only 15° with the orbital plane.

Influenced by Jacques Cassini's ideas (as shown by Schiaparelli), the fanciful Schrœter found a period of 23 *hours* 20 *minutes* 59·04 *seconds*, while not less biassed must have been Fritsch, in giving, from *four* days' observation, the period as 23 *hours* 22 *minutes*.

Never did scientists, however, indulge more freely in illusions than when the Jesuits of the Roman College undertook, in 1839, under De Vico's direction, the determination of the planet's rotation period. Eleven thousand micrometrical measures of spots taken by Palomba, with unprecedented zeal, gave the value of $23^h\ 21^m\ 21^s{\cdot}9345$.

The honour of demolishing these fanciful results belongs to Professor Schiaparelli, who, in a masterly discussion of all the observations,* concluded that "the rotation of $23^h\ 21^m$ or $23^h\ 22^m$ of Jacques Cassini, Schrœter and De Vico, is the result of a series of paralogisms and vicious circles."

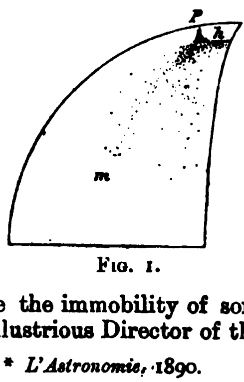


Fig. 1.

Taking as a base the immobility of some spots relatively to the terminator, the illustrious Director of the Milan Observatory

* *L'Astronomie*, 1890.

concluded that *Venus* constantly presents the same face to the Sun, or, in other words, that the rotation period coincided with the 224·7 days revolution round that luminary. Professor Schiaparelli's observations extend from 1877 December 8 to 1878 January 6. The fixed spots forming the ground work of the 224·7 days rotation may be described as follows (Fig. 1) :—

(1) An elongated dusky shading *hm* trending obliquely from the south cusp along the path of a great circle of the dichotomous or crescent phase ;

(2) A bright spot *h* near the cusp, bounded on the left by

(3) A slight diffused shading *p*.

Professor Schiaparelli notes that the spot *h* was seen by Professor Holden on 1877 December 15 ; that something like *h* and *p* was observed by Gruithuisen in 1813 and 1814, and by Vogel and Lohse in 1871.

What strikes us on an examination of these results, is an incredible cloudlessness and wonderful transparency of the atmosphere of *Venus* were these details to belong to the *body* of the planet. Seeing at once this difficulty, Professor Schiaparelli eluded it by stating that the character of these spots "seems to indicate rather atmospherical phenomena ; we consider them analogous to those which form on the surface of the Sun or *Jupiter*, and in default of something better, we will ask permission to similarly use them for determining approximately the rotation period. Cassini and Galileo did not do otherwise when studying the rotation period of *Jupiter* and the Sun."

Leaving at once aside any idea of comparison between the spots on *Jupiter* or the Sun and those of the atmosphere of *Venus*, we may say that we have every reason to believe that the latter can not be far different from the spots of our own gaseous envelope. The spots of our own atmosphere are white clouds floating in the air—a medium strongly diffusing sunlight. (We deem it quite useless to speak of volcanic smoke.) And as it is impossible to imagine clouds appearing black from above, the dusky spot *hm* can scarcely claim an objective existence. If atmospheric, it will at best be a break in a mass of clouds. But if so, is it not singular that this streak takes its position along the path of a great circle of the sphere passing through the cusps of the dichotomous or crescent phase ? Moreover, the atmosphere of *Venus* must be really very calm for a break in the clouds to remain unchanged in position for almost a month. Such constancy of form is somewhat incompatible with what we are witnessing in our aerial envelope, and dwindles into impossibility when we reflect that *Venus* receives twice as much heat as we do from the Sun, and that it is solar heat which sets the air in motion.

White cusp spots like *h* have been repeatedly seen, especially by Trouvelot. But the superior brightness of the limb, to which Sir William Herschel called attention in 1793, can satisfactorily account for them by stopping in the vicinity of the cusps the darkness along the terminator. "With regard to the cause of

this appearance" (the bright limb), says Herschel, "I may venture to ascribe it to the atmosphere of *Venus*, which, like our own, is probably replete with matter that reflects and refracts light in all directions. Therefore, on the border where we have an oblique view of it, there will be in consequence an increase of this luminous appearance."*

We should be somewhat cautious before accepting, as having objective existence, the dusky shading P. For if diffusion of light from the planet's atmosphere hides to our view all markings about the centre of the disc—where, however, the atmospheric effect is reduced to a minimum—we could not reasonably hope to define details almost on the limb itself.

Supposing, however, for one moment, that spots *h* and P are real, then analogies from the planet *Mars* would lead us to consider them as snow caps, *dimmed* in the case of *Venus* by the atmospheric effect. But the presence of snow caps on *Venus* would obviously be the *coup de grace* to the $224^{d}\cdot70$ rotation period. The snow on the illuminated hemisphere of a planet presenting always the same face to the Sun would not confine itself to a cap, but would rather distribute itself along the terminator.

It is, then, evident from our reasoning that the foundations of the $224^{d}\cdot70$ rotation period of *Venus* are delicate. The markings on which it rests would seem to be contrast effects arising from solar illumination. And we will presently show that fixity of atmospherical shadings with regard to the terminator of an inferior planet does not necessarily imply non-rotation of the body with reference to the Sun

Scarcely had Professor Schiaparelli announced his results, than M. Perrotin, starting from the apparent immobility of a vertical shading with regard to the terminator, concluded that *Venus* rotates in a period comprised between 195 and 225 days.† M. Perrotin's drawings are of very great value. But we should point out here that he confirms Professor Schiaparelli by using a spot which, in spite of its immobility, was rejected by the great Italian himself in his determination of the planet's rotation period. In fact, M. Perrotin's vertical shading is obviously identical with the spot seen by Schrœter in 1788, and of which Professor Schiaparelli said: "The general stability of its form, which lasted for more than two months, its constant parallelism with the terminator, its almost invariable distance from the latter suggest that we have to deal here with some phenomenon of the atmosphere of *Venus*, depending much more on the Sun, and consequently on the terminator circle, than on any axis of rotation whatsoever."‡

In 1895 M. Leo Brenner announced that he had discovered the rotation period of *Venus*, which he fixed, with an accuracy equalled only by De Vico's, at $23^{h}\ 57^{m}\ 7^{s}\cdot5459$.

Meantime more than one observer was engaged in confirming

* Paper read before the Royal Society on 1793 June 13.

† *L'Astronomie*, 1890. ‡ *Ibid.* p. 328.

the long rotation. The last observations reach us from Flagstaff.

At variance with all his predecessors and successors, Mr. Percival Lowell finds the markings of *Venus* "as distinct really as those of the Moon. . . . The period of rotation coincides with the period of revolution. *This planet is a desert.*" *

The characteristic feature shown by the Flagstaff observations is a black spot in the centre of the disc from which radiate black anomalous canals, which, to judge from their appearance, would seem to have the intention of extending beyond the limb. Surely such canals, dug as they are in a gaseous envelope, have nothing whatever to do with *Venus*.

For if we know anything certain about this planet it is that it has an atmosphere (in fact, we see it when *Venus* is projected on the vicinity of the Sun), and that this atmosphere is, very probably, denser than that of *Mars*. Now, if diffusion from the rarefied aerial envelope of *Mars* does not allow us to see details about the limb, we could not reasonably hope to see canals on the limb of *Venus*, supposing we are credulous enough to believe for one second in their objective existence.

To believe in the reality of Mr. Lowell's cytherean canals means to believe that the globe of *Venus*, with its atmosphere, is imprisoned in a cage of black hoops meeting about a common diameter directed along the visual ray. Under such circumstances we cannot help considering the whole of this anomalous canal system as entirely illusory, and the central black spot as merely the "pilula" of Fontana.

Last summer I undertook at Juvisy Observatory, under M. Camille Flammarion's direction, a systematic survey of the markings of *Venus*. The observations were made in broad daylight invariably, and the planet was examined at times for three or four hours in succession. No abnormal features were seen at any time. The markings were at all times exceedingly indefinite, and always somewhat doubtful. The impression given by the general appearance of the disc was identical with Sir John Herschel's description, given in his *Outlines of Astronomy* :—"The intense lustre of its illuminated part dazzles the sight and exaggerates every imperfection of the telescope. . . . We notice in it neither mountains nor shadows, but a uniform brightness, in which sometime we may indeed fancy, or perhaps more than fancy, brighter or obscurer portions, but can seldom or never rest fully satisfied of the fact."

The colour of the planet was of a beautiful chrome yellow by day. The limb was exceedingly brilliant; the terminator of the dichotomised disc dusky, particularly so about its central regions. From each of the cusps a diffused shading entered the disc apparently along the path of a great circle, perpendicular to the orbit of *Venus*, while midway between the terminator and the limb, somewhat nearer the former, an indefinite dusky marking

* *Bulletin de la Société Astronomique de France*, 1897.

extended occasionally from north to south, and almost parallel to the terminator. These various shadings are shown in the annexed Fig. 2.

The cusp markings, which seem to be of the same nature as Professor Schiaparelli's spot *hm* on the contrary phase, were always visible; but the vertical shading, which is analogous to

FIG. 2.

Schrœter's and M. Perrotin's streaks on the evening star apparition, had a periodical existence only. But when there, all three spots kept constantly the same positions with regard to the terminator, not the slightest trace of rotation being detected.

Obviously such markings are far too symmetrical to induce us to employ them in determining the rotation period.

Examining the causes governing the illumination of *Venus* when dichotomised, we find that such illumination obeys :—

(1) Lambert's law of the cosine.

(2) The increased brilliance towards the limb.

The simultaneous action of these two causes gives a very plausible explanation of the dusky cusp spots, from the fact that the superior luminosity of the border brightens the extremities of the duskiness along the terminator. And as the increase of brightness towards the limb, at first insignificant about the centre, becomes suddenly very marked in the immediate vicinity of the border, the luminous decrease along the terminator will be enhanced by contrast, almost to spots trending obliquely from the cusps along the path of a great circle of the sphere passing through them.

It is less easy to offer a satisfactory explanation of the vertical shading lying midway between the terminator and the limb. But we cannot consider it as having an objective existence; the more so as the same phenomenon is visible on the evening star phase of *Venus*, and we will not indulge in the wild fancies which would involve cutting the atmosphere of this planet into spherical ungulæ of alternately white and dusky material, having their common diameter at right angles to the orbital plane.

The only reasonable interpretation we can find for this marking is that of an enhanced whiteness about the terminator, such as that of fog particles floating in our morning and evening skies. This view is supported by the fact that the shading in question was not always present.

Everyone knows that *Venus* in quadrature shows not a dichotomous but a crescent phase. No one to my knowledge has found a satisfactory explanation of this phenomenon since Schrœter first called attention to it a hundred years ago. An attempt at an explanation was recently given by me,* namely, that it was due to the superior brightness of the limb, when the cusps would stand out "in noble relief, *through contrast and irradiation*, from the sombre central regions of the terminator." This is certainly so; but the interpretation given is not quite complete, and I am indebted for its full development to my friend, Abbé Moreux, whose theory may be summarised as follows:—

Let ABO (Fig. 3) stand for a quadrant of dichotomised *Venus*, OB the direction of the Sun, and CDEF the planet's atmosphere. The atmospheric illumination does not stop at DO but at CG. Towards OG we are looking on less atmospheric particles than at

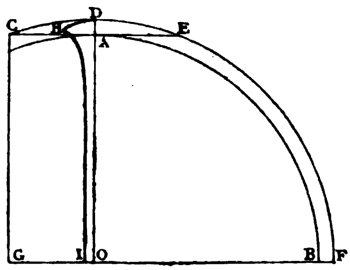


Fig. 3.

ADC where the luminosity is very considerably increased. Hence the final terminator curve will take a path such as DHI with a preponderance of brilliance at the exaggerated cusp H.

Owing to the great analogy of dimensions, we are fully justified in considering *Venus* as being the planet the most resembling our Earth. Now observation shows that the heights of

* *Journal of the British Astronomical Association*, vol. viii. No. 1.

the atmospheres of the two planets are also comparable, since that of *Venus* would measure, according to D'Abbadie, some 250 miles ($2''$ on a diameter of $62''\cdot8$ during the 1882 transit on the Sun), while that of the Earth extends from 190 to 212 miles, according to M. Liais, from observations on the influence of the highest regions of our atmosphere upon twilight at Rio Janeiro.* Here I think the comparison is not quite in favour of the height of the Earth's atmosphere, for if the excellent background of the corona cannot fail to show the slightest particles of the most rarefied regions of the atmosphere of *Venus*, we could not speak as confidently of the value of atmospheric heights based on twilight observations.

What the density of the atmosphere of *Venus* is we do not know, for we cannot rely on the discordant values of horizontal refraction (Schrœter $30'\ 34''$; Mædler $43'\cdot7$.)† It is probably not far different from our own. *Venus* receiving from the Sun an amount of heat per unit of area which is to what we enjoy as $\left(\frac{1}{\cdot723}\right)^2 = \frac{1\cdot91}{1}$, evaporation must be more active on this planet than on the Earth. But we should hesitate in assuming that the cytherean skies are usually overcast, for the reason that if the greater heat stimulates evaporation, the converse process of precipitation would be slackened for the same reason.

Applying to *Venus* Professor Langley's investigations on terrestrial atmospheric absorption, we should have the normally falling ray losing 40 per cent. of its intensity in its passage downward through the atmosphere. Of the 60 per cent. reaching the planet's surface less than one-quarter would be diffused by yellow sand itself, that is, 14 to 15 per cent.

And this quantity must lose again 40 per cent. in its return passage through the gaseous envelope. Thus no more than $\frac{1}{12}$th of the luminous rays ‡ would reach the eye of an observer placed in space. In spite of its apparent exiguity, this $\frac{1}{12}$th of the total radiation which we would see about the centre of the disc viewed along the radius vector, is a very considerable quantity, and one which would doubtless allow us to have a tolerably fair idea of the distribution of light and dark spots over the planet's surface, were it not for the supreme blurring cause—luminous diffusion from the planet's atmospheric particles. The effect of this diffusion is to reduce the contrast between the light and dark areas, to the utter blurring of the image.

Beneath its dazzling gaseous envelope, showing no more than some fugitive markings—at best functions of the phase—rotates the invisible globe of *Venus* in a period which is quite unknown. Terrestrial and Martian analogies, however, as well as the existence of some sort of relation between the masses of the planets and their rotation periods, would give to *Venus* a diurnal

* Moore's *Meteorology*, London, 1894, pp. 16–17.

† Chambers's *Descriptive Astronomy*, 3rd edition, p. 68.

‡ Flammarion, *La Planète Mars*, p. 89.

rotation comparable to that of the Earth or *Mars*—a view supported by the great probability that the extraordinary results claimed by the long rotation could not reasonably have been brought about by tidal friction.

Long-enduring Spots on Jupiter. By A. Stanley Williams.

There are several cases on record of spots on *Jupiter* which have remained in existence for periods measured by a number of years. The first authentic instance of the kind relates to the celebrated spot which appeared in the latter half of the seventeenth century, and which may possibly be identical with the present well-known "red spot." This last-named object has been under constant observation for at least twenty years, whilst its existence can be traced for perhaps thirty or forty years more. A third instance is that of the brilliant white equatorial spot which attracted so much attention in 1880, and remained visible for at least five or six years. Such cases of extreme longevity are not only interesting in themselves, but are of extreme importance in connection with questions relating to the present physical condition of *Jupiter*.

The object of the present paper is to put on record another instance of remarkable longevity in a Jovian spot. The object in question was a brilliant white spot situated on the north edge of the great north equatorial belt. For convenience it is designated C. The following is a complete list of all the observed times of transit of this spot which have come to the writer's notice,* together with the corresponding longitudes, all uniformly expressed according to the "System II." of the late Mr. Marth's ephemerides for 1887 and 1888.† The zero meridian of this system has several times been subsequently shifted 10°, in order to make it correspond nearly with the centre of the red spot. The longitudes given here refer to the unshifted zero meridian. For the observations made by the writer, the weights attributed to them at the time have been added. These weights range from 1 (bad) to 5 (good). An additional column gives the brightness of the spot according to a uniform scale, in which eeB=most exceedingly bright, eB=exceedingly bright, vB=very bright, B=bright, mB=moderately bright, F=faint, vF=very faint, eF=exceedingly faint. The total number of transits is 153.

* The spot also appears in some of the Lick photographs of *Jupiter*, but it has not been thought necessary to measure these, the visual observations being already sufficiently numerous.

† The daily rate of rotation of this system is 870° 2700, corresponding to a period of rotation of $9^h\ 55^m\ 40^s{\cdot}63$.

Observations of Bright Spot C.

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1885.	h m		°		
Jan. 27	11 1	...	260·1	...	Denning.
Mar. 4	10 21	...	250·3	...	"
7	7 54	...	252·6	...	"
11	11 4	...	248·8	...	"
12	6 57	...	249·9	...	"
14	8 29	...	246·1	...	"
19	7 50·3	...	(254·4)	...	Terby.
28	10 3	...	247·3	...	Denning.
31	7 32·8	...	247·3	...	Terby.
Apr. 2	9 8	...	245·4	...	Denning.
4	10 45	...	244·5	...	"
12	7 19	...	241·9	...	"
18	12 20	...	245·1	...	"
19	8 7	...	242·4	...	"
19	8 11·7	...	245·3	...	Terby.
20	13 49·7	...	239·7	...	Barnard.
23	11 23	...	241·6	...	Denning.
25	12 55·2	...	237·7	...	Barnard.
May 1	8 0	...	240·3	...	Denning.
June 1	8 33	...	234·0	...	"
3	10 18	...	237·6	...	"
13	8 19	...	226·4	...	"
20	9 11	...	228·2	...	"
1886.					
Apr. 6	7 27	...	162·4	...	"
13	8 14	...	162·6	...	"
25	8 4	...	160·9	...	"
27	9 42	...	160·7	...	"
30	7 13	...	161·5	...	"
1887.					
Feb. 26	15 45	3	93·2	B	Williams.
Apr. 8	14 9	3	81·1	"	"
16	10 46	est.	81·7	vB	"
20	13 51	3	75·1	B	"
25	13 0	3	76·2	vB	"
30	12 6	5	75·5	eB	"
May 10	10 19·5	4	74·8	"	"
14	13 39	3	76·7	vB	"

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1887.	h m		°		
June 8	9 10·5	...	71·7	...	Terby.
10	10 45	3	69·3	B	Williams.
10	10 45·5	...	69·6	...	Terby.
15	10 0	est.	73·3	B	Williams.
17	11 36	4	71·7	"	"
20	9 5·5	...	71·4	...	Terby.
22	10 36	3	66·4	B	Williams.
22	10 38·5	...	67·9	...	Terby.
25	8 16·5	...	72·7	...	"
27	9 48·5	...	68·6	...	"
July 2	8 57·5	...	68·7	...	"
14	8 51·5	...	66·8	...	"
26	8 42·5	...	62·7	...	"
1888. Mar. 25	14 7	3	19·7	vB	Williams.
Apr. 1	14 56	1	21·8	B	"
3	16 33	3	21·2	vB	"
6	13 53·5	4	15·8	"	"
13	14 41·7	4	17·6	eB	"
20	15 27	5	17·7	eeB	"
May 3	11 4	3	14·0	vB	"
10	11 57	4	18·9	"	"
12	13 30	3	15·9	"	"
14	15 9	3	16·5	"	"
15	11 11	2	23·1	B	"
19	14 17·5	3	18·0	eB	"
20	10 10·5	3	18·5	vB	"
24	13 25	1	17·6	"	"
27	10 48	3	14·0	"	"
June 1	9 59	4	16·3	eB	"
3	11 38	2	16·8	vB	"
10	12 20·5	2	15·0	"	"
13	9 49	5	14·5	"	"
22	12 13	1	14·4	B	"
July 19	9 30	1	12·8	"	"
Aug. 22	7 45	est.	14·6	vB	"
1889. Mar. 2	17 10	1	11·1	"	"
26	17 55	1	14·1	F	"

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1889.	h m		°		
Apr. 22	14 42	1	25·4	F	Williams.
July 4	9 56·5	3	30·9	mB	"
6	11 29·1	2	27·6	"	"
21	8 43·8	2	22·9	"	"
30	11 8·7	1	23·2	vF	"
Aug. 26	8 26·7	est.	21·8	"	"
Sept. 12	7 45	...	29·3	...	Denning.
1890.					
May 20	14 59·6	2	18·6	mB	Williams.
27	15 46·1	1	18·9	"	"
30	13 15	1	18·6	B	"
July 3	11 13·3	2	17·6	"	"
22	11 58·2	1	22·5	vF	"
24	13 30·4	2	19·0	F	"
Aug. 1	10 4·5	2	17·7	mB	"
3	11 49·8	3	22·2	"	"
5	12 30·2	2	23·7	"	"
8	10 51	1	18·6	"	"
15	11 37·6	3	19·3	"	"
30	9 0·4	1	19·3	"	"
Sept. 4	8 12·5	2	21·8	"	"
6	9 47·8	2	20·0	F	"
8	11 21·9	2	17·4	"	"
16	8 3·5	3	19·5	"	"
Oct. 10	7 53	2	17·8	mB	"
17	8 44·6	1	20·0	"	"
Nov. 1	6 10·1	2	18·2	F	"
Dec. 7	6 3·3	1	16·0	...	"
1891.					
June 17	15 23·3	3	13·7	mB	"
July 4	14 22·1	2	11·9	"	"
Aug. 7	12 13·8	...	6·7	"	"
12	11 19·4	3	6·4	"	"
16	14 35·3	4	5·7	"	"
19	12 4·9	4	6·0	B	"
28	14 22·2	4	2·7	mB	"
29	10 16·8	3	4·8	"	"
Sept. 5	10 57	4	1·9	"	"
9	14 6·1	2	357·8	F	"

Date.		G.M.T. of Transit. h m	Weight.	Longitude. °	Brightness.	Observer.
1891. Sept.	10	9 56	2	357·0	F	Williams.
	12	11 35·7	2	358·1	mB	„
	22	9 40·5	est.	(352·2)	B	„
	27	8 57·6	3	358·0	mB	„
Oct.	4	9 39·7	3	355·7	vB	„
	28	9 28	2	354·9	mB	„
	30	11 10·5	2	357·3	F	„
Dec.	20	8 39·7	1	2·4	mB	„
1892. July	7	14 35·3	3	352·4	„	„
Aug.	20	11 11	est.	(1·7)	„	„
	21	16 48·8	2	356·3	F	„
	22	12 42·0	3	357·4	„	„
	26	16 3·9	est.	358·5	„	„
	31	14 52·9	4	349·7	mB	„
Sept.	8	11 38·3	3	355·3	„	„
	10	13 13	2	353·3	F	„
	15	12 17	3	351·4	vF	„
	17	13 55·8	2	351·9	F	„
	18	9 56	1	357·4	„	„
	24	14 35·3	3	348·6	„	„
Oct.	2	10 59·8	1	341·7	vF	„
	6	14 12	2	339·5	„	„
	7	10 1·1	3	338·2	F	„
	9	12 1·4	2	(351·7)	„	„
	11	13 19·5	3	339·7	vF	„
	12	9 13·1	2	341·2	„	„
	23	13 15	2	341·7	„	„
Nov.	7	10 27	3	335·4	„	„
	24	9 34·8	3	338·8	„	„
	27	7 4·2	2	338·5	„	„
Dec.	4	7 51·4	1	338·6	vF?	„
	6	9 30·4	2	338·8	eF	„
	11	8 43·9	2	341·8	„	„
	13	10 21·8	est.	341·2	...	„
	21	6 53·8	est.	336·8	eF	„
	23	8 35·3	2	338·4	vF	„
1893. Aug.	14	12 53·5	2	332·8	mB	„
	16	14 24·2	1	(328·1)	...	„

Date.	G.M.T. of Transit.	Weight.	Longitude.	Brightness.	Observer.
1893.	h m		°		
Aug. 23	15 25·9	1	337·1	F	Williams.
28	14 31	est.	335·3	F?	"
Sept. 4	15 12	1	332·1	eF	"
Oct. 8	13 3·3	3	325·7	F	"
Nov. 6	12 4·5	1	331·6	vF	"

It will be seen from the foregoing list that the spot was under observation from 1885 January 27 to 1893 November 6, a period of 3205 days, or nearly nine years. Such a long duration is the more remarkable when it is considered that the spot was of comparatively small dimensions, its diameter, in fact, not much exceeding that of Satellite III.

The variations in the rate of motion of the spot are no less remarkable than its longevity. It is a very significant circumstance that none of these long-enduring spots have preserved a uniform motion. The great red spot even, it is well known, has varied considerably in its rate of motion from time to time. The present spot C is no exception to this rule. The following table gives its approximate period of rotation for each opposition, together with the number of rotations comprised between the first and last observation. The observations of 1886 are insufficient to give more than an approximate result, but the position of the spot in that year relative to that which it occupied in 1885 and in 1887 shows that its real rate of rotation in the opposition of 1886 probably differed little from what it was in the other two years :—

Opposition.	Rotation Period. h m s	No. of Rotations.	Opposition.	Rotation Period. h m s	No. of Rotations.
1885	9 55 32·3	348	1890	9 55 40·3	485
1886	(36·2)	58	1891	36·2	449
1887	32·	6280	1892	35·7	408
1888	38·8	362	1893	35·8	203
1889	43·7	468			

The following is a short history of the motion of the spot gathered from the foregoing table in conjunction with the previous list of observations. From 1885 January 27 to 1887 July 26 the motion was almost perfectly uniform, the rotation being performed in a period of $9^h\ 55^m\ 32^s{\cdot}5$. This rate of motion seems to have been continued almost up to the commencement of the observations of 1888, when a sudden check occurred, and the spot came nearly to a standstill with respect to Marth's zero meridian. This state of things continued almost unaltered all through the opposition of this year. In 1889 March we still find the spot in nearly the same longitude, but its motion then became still slower, so that the mean period of rota-

tion for the apparition was as long as $9^h\ 55^m\ 43^s{\cdot}7$. A slight increase, however, occurred in the velocity of the spot in 1890, whilst in 1891 a still further increase in velocity took place, the period of rotation diminishing to $9^h\ 55^m\ 36^s{\cdot}2$; and this accelerated rate of motion was maintained practically unaltered, though with temporary slight variations, in the two succeeding years. The spot was unfortunately lost sight of after 1893 November 6, owing to the enormous changes which were occurring in that year in the region of the north equatorial belt, changes which quite altered the aspect of this part of the planet in the course of a few months.

In connection with the probable cause of the arrestment of the spot's motion in 1888, it is necessary to consider the conditions prevailing along the whole zone in which it was situated. In 1887 a somewhat abnormal condition of affairs had prevailed along this zone. Whilst in one hemisphere of *Jupiter* the spots were rotating at an average rate of $9^h\ 55^m\ 41^s{\cdot}3$, in the other hemisphere the spots—amongst them our spot C—were rotating in $9^h\ 55^m\ 32^s{\cdot}2$.* It is obvious that such a state of things could not endure permanently if the two series of spots were at the same level, but that ultimately the swifter spots must overtake and collide with the more sluggish ones. This is exactly what appears to have happened, with the result that the motion of the swifter spots was arrested, and made to conform to that of the more sluggish ones. The velocity of the material of the zone consequently became nearly uniform right round the planet. Subsequently to 1889 the acceleration in velocity of spot C that then occurred seems to have affected more or less the whole zone.

An interesting point about the arrestment of the velocity of spot C is that it was not perfectly regular. There were obviously slight minor fluctuations from time to time in the position of the spot. Such fluctuations might well be expected to occur in the case of two opposed masses of material, possessed of differing velocities, coming into a state of equilibrium.

A few words should be said relative to the appearance of the spot. When at its greatest intensity it was a very brilliant object, appearing as a definite disc, slightly oval in shape, and rather larger than satellite III. But at other times, even when brilliant, it appeared quite indefinite, whilst on several occasions feebler extensions were seen in an east or west direction. It is probable that such variations in aspect are answerable for some of the discordances in the observations.

The fluctuations in the brightness of the spot, though considerable, were not nearly so great or so sudden as were those experienced by the white equatorial spot of 1880. It is probable, too, that some of the differences here recorded had an atmo-

* Further particulars concerning this anomalous state of things will be found in the writer's *Zenographical Fragments*, p. 18.

spheric origin. The visibility of very large spots, provided that they are not faint, is almost independent of the state of the seeing. But the smaller a spot may happen to be, the more is its visibility affected by poor definition. Such a spot as C would not be altogether obliterated by the worst and most confused seeing obtainable in practice, but it would certainly appear less conspicuous under such conditions.

Equatorial Comparisons of Neptune with 114 (o) *Tauri,* 1897 *December.* By John Tebbutt.

In consequence of illness and cloudy weather I found it impossible to obtain earlier comparisons than those which accompany this letter. The observing conditions were, however, excellent on each evening, and the measures were made with the filar micrometer on the 8-inch equatorial and in a bright field. Each coordinate of the planet is the result of twenty comparisons. The mean place of the star for 1897·0 is derived from the following Catalogues: Washington, 1860, 3rd ed.; Radcliffe, 1860–1890; Glasgow, 1870; and Greenwich, 1864, 1872, 1880. The precessions with the secular variations have been employed from the Radcliffe Catalogue, 1890, with checks from the same elements in the Greenwich Catalogue, 1880, and the annual proper motions in R.A. and N.P.D. have been adopted as $-0^s\cdot0011$ and $-0''\cdot006$. By assigning equal weights to the Catalogues the mean place for 1897·0 is R.A.$=5^h\ 21^m\ 26^s\cdot68$ N.P.D.$=68°\ 9'\ 4''\cdot3$. The star is also one of Professor Newcomb's Standard Clock and Zodiacal stars.

In the last column of the accompanying table will be found a comparison of the observed places with the transit ephemeris on page 281 of the *Nautical Almanac.* The *Nautical Almanac* does not furnish any semidiameter for the planet, but the *American Ephemeris* assigns $1''\cdot3$ for the time of opposition. This value must, I think, be much too great.

Results of Micrometer Comparisons of Neptune and 114 (o) Tauri.

1897.	Windsor Mean Time.	Planet Centre—Star.		Star Reductions.		Parallax Corrections.		Geocentric Apparent Place of Planet's Centre.		Correction to *Nautical Almanac.*	
		R.A.	N.P.D.	R.A.	N.P.D.	R.A.	N.P.D.	R.A.	N.P.D.	R.A.	N.P.D.
	h m s	m s	′ ″	s	″	s	″	h m s	° ′ ″	s	″
Dec. 22	10 55 18	−0 53·06	+6 26·5	+6·02	−9·4	0·00	+0·2	5 20 39·84	68 15 21·6	−0·12	+3·1
„ 23	10 33 33	−1 0·16	+6 32·2	+6·03	−9·4	0·00	+0·2	5 20 32·75	68 15 27·3	−0·15	+3·1
„ 24	10 9 27	−1 7·15	+6 37·9	+6·03	−9·4	0·00	+0·2	5 20 25·76	68 15 33·0	−0·11	+3·1
„ 26	10 10 5	−1 21·32	+6 48·7	+6·05	−9·3	0·00	+0·2	5 20 11·61	68 15 43·9	−0·12	+2·8
„ 27	9 59 10	−1 28·27	+6 54·4	+6·05	−9·3	0·00	+0·2	5 20 4·66	68 15 49·6	−0·09	+3·0
„ 28	10 19 24	−1 35·40	+6 59·9	+6·06	−9·3	0·00	+0·2	5 19 57·54	68 15 55·1	−0·14	+3·0

Windsor, New South Wales:
1898 *January* 23.

Nebulæ observed at the Royal Observatory, Cape of Good Hope.

(Communicated by Dr. David Gill, C.B., &c., H.M. Astronomer.)

Name.	R.A. 1860.	Dec.	Authority for position.	Description.	Observer.	
	h m s	° ′				
N.G.C. 1398, Winnecke	3 32 58·2	−26 47·9	Equ. comp.	Small round neb. Bright in middle	F.	1887 Mar. 17
C.P.D. −47°, 418 New	4 7 34·3	−47 37·3	C.P.D.	Nebulous star (8·8 vis., 10·4 photo.), nebulosity 1′ in diameter	I.	1897 Feb. 5
New	11 34	−45 42	Circle reading	...	F.	1884 July 27
New	14 14	− 5 21	Circle reading	...	F.	1883 Sept. 20
Cor. D.M. −35°, 9764 New	14 36 45	−35 34·7	Cor. D.M.	Elliptical neb. surrounding two stars as if they were the foci of an eclipse, mags. 9·5 and 10. The Cor. D.M. mag. of the chief star is 9·7. In a high-power field with Lac. 6076	I.	1897 Feb.
C.P.D. −32°, 3780 N.G.C. 5824, Barnard	14 55 22·7	−32 30·8	C.P.D.	C.P.D. mag. = 9·4. Bright small nebula, mag. 9·0	F.	1883 Sept. 25
New	16 23	−25 45	Circle reading	Follows a faint star 4·5 secs., and is 0′·5 S.	F.	1887 Sept. 8
N.G.C. 6302, Barnard	17 4 17·5	−36 55·8	Equ. comp.	Small, very bright nebula	F.	1887 Sept. 11
New	19 20 36	−46 59	Circle reading	A faint nebula joined to, but *sp*, a 9·5 mag. star. There is perhaps a stellar nucleus.	I.	1897 Nov. 11

Name.	R.A. 1860. h m s	Dec. ° ′	Authority for position.	Description.	Observer.
Brit. Ast. Assn. Journal, vol. vi. p. 257, C.P.D. −46°, 9730	19 23 23	−46 11·2	C.P.D.	C.P.D. mag. = 9·4, an even patch of light 3″ by 2″	I. 1895 Oct. 16
New	20 55	−56 48	Circle reading	Equal to a 9·7 mag. star, elongated 15″; perhaps a small group of stars or a ring nebula	I. 1897 Nov. 26
Swift, 1897 Aug. 8.	22 33 30	−45 31	Circle reading	...	F. 1886 Dec. 26
New	22 49	−44 8	Circle reading	...	F. 1886 Dec. 25
N.G.C. Apx. 1459, Barnard	22 49 20·1	−37 12·6	Equ. comp.	Differs from Dreyer 10 secs. and 2	F. 1886 Dec. 16
G.C. 4952, *h* 4000	23 28 45	−38 43 2	Alignment	Between Cor. D.M. −38°, 15559 mag. 9·7 and −38°, 15561 mag. 9·9, near the former. Impression = 11th mag. The coordinates in the N.G.C. are 30′ ± in error	I. 1897 Dec. 18

Observers: F., W. H. Finlay, 7-inch and 6-inch equatorials; I., R. T. A. Innes, 7-inch equatorial.

Royal Observatory, Cape of Good Hope:
1898 *January* 21.

List No. 6 of Nebulæ discovered at the Lowe Observatory, Echo Mountain, California.* By Lewis Swift.

No.	Date. 1897	R.A. h m s	Dec. ° ′ ″	Descriptions.
1	Dec. 25	2 11 10	−31 39 15	pF, pS, R, distant D ✱ nf.
2	22	2 25 45	−34 42 0	eeeF, S, R, D ✱ nearly p, np of 2.
3	22	2 26 0	−34 41 42	eF, eS, R, F ✱ nr n.D ✱ np, sf of 2.
4	22	2 26 15	−36 28 55	pB, pS, vE.
5	22	2 37 0	−28 37 0	eeF, S, R, 3 D stars nf, each about 7″.
6	22	2 40 35	−28 22 35	eeF, S, R, D ✱ np.
7	22	3 7 30	−25 42 0	eeF, S. R, 2 f stars near sp point to it.
8	26	3 35 40	−27 11 10	eF, eS, lE, ✱ close nf, stellar.
9	26	3 50 40	−28 26 15	eF, S, R, F ✱ in contact nf.
10	23	4 8 30	−32 49 48	vF, v, S, R, partial resolvability suspected. 1531–2 in field.
11	26	4 52 0	−28 41 35	eeeF, pL, iR, D ✱ 24ˢ f point to it.
12	Nov. 30	5 2 30	−20 37 15	eeeF, pS. bet 2 stars, eeedif. Close to eeeF D ✱
13	Dec. 26	5 15 10	−25 11 30	eeeF, vS, R, 7ᵐ ✱ 15ˢ p. Is nearly obliterates it eeedif.
14	1	5 30 0	−23 36 30	eeF, pS, R, 7ᵐ ✱ close f, sf of 1980.
15	Nov. 30	5 44 0	−30 31 55	eeeF, pS, R, F ✱ np, sev B st sf, 3 st n curved.
16	Dec. 1	5 53 0	−23 11 30	pB, pS, R, in vacancy, sev B st f.
17	1	5 56 45	−23 41 30	B, L, R, bet a ✱ nf and v wide D ✱ np.
18	26	6 1 5	−27 51 50	vF, pS, lE, ✱ in contact nf, n end like a brush.
19	28	9 18 10	−32 2 55	pF, cS, vE, 10ᵐ ✱ close sp.
20	28	9 54 5	−26 42 35	eeeF, eeS, R, eF D ✱ close S, eeedif, 3078 in field.
21	28	10 11 20	−33 3 10	eeF, pS, iR, in centre of trapezium.
22	30	10 16 38	−33 46 15	vF, cS, R, 9ᵐ ✱ p close f.
23	30	10 24 30	−35 3 15	eeeF, eeS, R, eF, ✱ in contact S, p of 2.
24	30	10 35 12	−35 31 35	eeeF, eeS, R, eF, ✱ in contact S, f of 2.
25	29	10 36 0	−35 5 25	eeeF, eS, R, eeF D ✱ near S.

Notes to numbers 23 *and* 24.

Here are two nebulæ singularly placed whose descriptions, as will be seen, are identical in every particular. I ran across a very faint nebula which I found was N.G.C. No. 3267. Near following was an exceedingly faint and very close double star, which, with a power of 132, looked as if the north one was

* Lists Nos 2, 3 and 4 will be found in *Monthly Notices*, vol. lvii. pp. 629, 631, and vol. lviii. p. 18; Lists Nos. 1 and 5 in the *Astronomical Journal*, Nos. 388, p. 27, and 422 p. 111.

an exceedingly small nebula of unimagined faintness. With a power of 200 my suspicion that it was not a star was confirmed.

In a few minutes I ran across another, which in every particular was exactly like it, both being north of its companion star, and of the same distance apart about 4′, and of the same size and faintness. But for the excellent seeing and superiority of my periscopic eyepiece for revealing faint nebulæ, they would have escaped detection. If they are as distant as their companion stars, they must vastly exceed in volume the orbit of Neptune, and yet are self-luminous.

List No. 7 of Nebulæ discovered at the Lowe Observatory, Echo Mountain, California. By Lewis Swift.

No.	Date.	R. A. 1900·0.	Dec. 1900·0.	Description.
	1898.	h m s	° ′ ″	
1	Jan. 22	9 23 0	−42 24 30	pB, S, R, 7^m * nf, D * p.
	1897.			
2	Dec. 30	9 45 0	−32 23 5	pB, pS, eeE, spindle, 7^m * np, np of 2. Not 3038.
	30	9 45 35	−32 25 5	eeF, eS, 3F st close f, sf of 2.
4	30	9 52 32	−31 48 0	vF, S, R, $7\frac{1}{2}^m$ * np, 2 or 3 Fst near.
5	30	10 24 30	−35 3 15	eeeF, eeS, R, eF * in contact sp of 2.
	1898.			
6	Jan. 1	10 26 3	−28 12 30	pF, vS, R, trapezium near sp.
7	1	10 27 10	−29 52 35	eeeF, pL, R, D * nr sf, * with dist comp. f and p.
	1897.			
8	Dec. 30	10 35 12	−35 31 35	eeeF, eeS, R, eF * in contact sf of 2.
	1898.			
9	Jan. 1	11 17 0	−28 27 30	pB, pS, R, 10^m * close n little f, 7^m * f.
	1897.			
10	Dec. 29	11 49 35	−37 21 5	eF, vS, 7^m * sp.
11	30	12 0 30	−27 22 45	vF, L, lE, 8^m * nr f, np of 2.
	1898.			
12	Jan. 1	12 0 35	−27 24 25	eeeF, pL, eE, 3 8^m st f, sf of 2.
13	31	12 3 25	−31 2 15	pB, vS, * close sf, vE 45°.
14	1	12 14 28	−25 37 15	pB, S, R, bet 4 st sf and 8^m * np.
15	30	12 18 45	−39 14 0	pF, vS, R, close p of 4373. See note.
16	1	12 20 0	−25 30 15	eF, vS, R, bet 7^m * sf and 8^m * np, v dif.
17	30	12 22 5	−38 48 50	pB, pL, R, 7^m * with dist comp. near p.
18	1	12 45 0	−25 22 15	eeeF, S, R, 8^m * nf.
19	31	12 46 0	−29 27 35	B, S, lE, 9^m * near sf.
20	31	13 11 10	−31 33 45	pB, pS, R.
21	31	13 12 5	−31 7 45	eeeF, pL, R, 9^m * nr sp, e dif.
22	31	13 18 25	−29 47 37	eeF, pS, R, trapezium nr sf.
23	30	13 31 0	−33 35 0	pL, pS, lbM.
24	30	13 31 10	−33 33 55	eeeF, eeS, like D *, one nebulous. Note.
25	30	13 51 35	−39 31 50	8^m * in eeeF nebulosity. See note.

Notes.

No. 15 forms D nebula with 4373. Strange *h* failed to see it.

No. 24. This is another of that variety resembling a close D ✱, making four I have lately found, dis. about 4″. That they are physically connected is highly probable.

No. 25. This is a nebulous star, the only one I have ever found. The central star is about 8^m, and surrounded with an exceedingly faint atmosphere. An 8^m star follows 15^s, which was free from nebulosity.

Some of the above list are quite interesting objects, especially for their brightness and size, and their remaining so long undiscovered. This list makes the number of nebulæ discovered at this Observatory 205. I find the southern sky visible from this Observatory an interesting field for the search of nebulæ.

List No. 8 of Nebulæ discovered at the Lowe Observatory, Echo Mountain, California, for 1900·0. By Lewis Swift.

No.	Date. 1898.		R.A. h m s	Dec. ° ′ ″	Description.
1	Feb.	22	5 29 20	−36 28 30	eeeF, eeS, eeeE, eee dif. See note.
2		14	5 30 8	−23 24 15	eF, vS, R, 8^m ✱ f 10^s in field with 1979.
3	Jan.	31	5 47 40	−38 22 45	eeeF, S, cE, semi circle of 3 st, S, v dif.
4	Feb.	20	9 31 5	−11 56 30	pB, pL, R, 2 st near f.
5		19	9 39 40	−31 18 35	eF, S, R, vF ✱ close nf, pB ✱ near sp.
6	Jan.	12	9 45 5	−32 27 40	eeeF, pS, vE, bet below ✱ and 8^m ✱ p, nf of 2.
7		12	9 45 30	−32 27 45	eeeF, eeeS, R, D ✱ close sf, sp, of 2.
8	Feb.	19	9 52 40	−31 47 40	vF, pS, R, 8^m ✱ p.
9		15	9 55 25	−29 10 30	eeeF, pS, cE, trapezium n and nf, D ✱ np.
10		14	9 59 25	−27 4 50	eeF, L, cE, no B ✱ nr, no Δ as per 3113.
11		15	10 27 30	−23 32 10	eeeF, eS, eE, 8^m ✱ close p, eee dif.
12		15	10 31 30	−23 34 10	eF, pS, R, bet 2 D st sp and nf.
13		22	10 32 35	−10 35 55	CB, eS, Stellar.
14		14	10 33 25	−26 32 20	pF, pS, D ✱ nr p. See note.
15	Jan.	14	10 58 30	−15 41 45	eeF, eeS, looks like a D ✱.
16	Feb.	12	11 26 50	−29 52 40	vF, pS, R, sf of 3717.
17		22	11 44 0	−11 45 40	eF, cL, iR, Δ with ✱ n and another f.
18		20	11 45 25	−19 1 57	B, S, eE, a ray.
19		15	12 14 10	−25 35 20	pF, vS, R, 8^m ✱ nr np.
20		15	12 35 15	−36 13 20	pF, vS, 2 or 3 vF st in contact.
21		23	12 44 20	− 3 51 25	eeF, L, eE, 7^m ✱ nr a little f.
22	Jan.	31	12 55 0	−31 43 50	eeF, pS, R, 10^m ✱ nr nf.
23		30	13 59 40	−38 43 40	eeF, pS, R, bet 2 st, nr centre of trapezium.
24	Feb.	22	14 6 50	−30 3 33	F, pS, R, surrounded with sev F st.
25		22	14 28 20	−27 7 18	pB, eS, R, looks like a D ✱ one nebulous.

Notes.

N.G.C. 3145. I make the place of this interesting nebula for 1860 10^h 3^m $3^s - 11° 38' 45''$ vB, L, vE, much obscured by proximity to λ Hydræ np. New Gen. Catalogue has 10^h 3^m $18^s - 11° 44' 18''$, F. pL, R. It is very strange H. should say nothing about the star. As, however, our places are not very wide apart, I assume that my object is identical with 3145, yet that he should call it round is another mystery. It is not permissible to suppose that since its discovery in 1786 any change has taken place.

No. 1. This list is another hair line nebula, much resembling No. 7, list 4. There is a slight bulging in the centre, but it requires very close scrutiny to see it. They must be rings or flat disks placed parallel to our line of sight. In the field preceding there are several stars forming a segment of a large circle, and 3 stars like belt of *Orion*. No bright star near.

No. 14. This is not one of Sir John Herschel's 9. I have another near; stellar.

No. 19. List No. 6, as published in A.J. and perhaps other publications, contains a typographical error. For Dec $-22°$ read $32°$.

A Remarkable Object in Perseus. By the Rev. T. E. Espin, B.A.

On the night of January 16, while sweeping for red stars and stars with remarkable spectra, I passed suddenly from the starry background into what appeared to be a cloud. Although the night was very clear, yet I felt convinced it was a cloud, and continued my sweep. At the end of the sweep the telescope, as is usual, was moved 40′ south and the return sweep made. I again came upon the peculiar obscuration. My suspicions were aroused, as it seemed strange that on a clear sky there should be a small cloud, and that stationary. I waited twenty minutes, and then re-examined the object, and found it still there. I marked it on the B. D. charts, and next morning turned to the New General Catalogue of Nebulæ and the Addenda, but could not find it. On January 24 I re-examined it, and by rapid sweeping laid down its limits. They are as follows :—

$$\left.\begin{array}{llll} \text{In R.A. from} & 4^h\ 23^m\ 30^s & \text{to} & 4^h\ 28^m\ 30^s \\ \text{Decl.} \quad ,, & +50°\ 15' & ,, & +51°\ 14' \end{array}\right\} 1855.$$

This gives as its centre :—

R.A. 4^h 26^m 0^s. Decl. $+50° 44'\!\cdot\!5$ (1855).

It was observed again on January 25. The blotting out of the stars was very marked, and the object seemed more remarkable than ever. It is elliptical, major axis P=336°. It was also observed on February 16 and February 17. An attempt was made to photograph the region on January 24, but the night was very unsteady, and though the exposure was carried on for two hours, the plate only gives stars to the 12th magnitude. N.G.C. 1624, which had been picked up independently, had left

a trace on the plate, but there was no trace of the new object. A photo was again attempted on February 17, but at the end of twenty-five minutes it clouded up. Meantime I had written to Mr. Heath at Edinburgh, and he informs me that Dr. Halm found it on February 17, with the 6 in. refractor, without much difficulty. Mr. Heath also saw it, and says: "To both of us it conveyed the impression of an attenuated cloud-like object or haze, producing a difference of colour from that of the neighbouring sky, and, as you remark, dimming the tiny stars which appear to shine through it."

Ephemeris for Physical Observations of the Moon, 1898 *April* 16 *to* 1899 *January* 1. By A. C. D. Crommelin.

This ephemeris has been constructed in the same manner as those communicated by Mr. Marth, and commences at the point where his last one terminates (vol. lvii. 8, p. 613). The inclination of the Moon's equator to the ecliptic has been taken as $1^\circ.523$, the value employed by him for the last two years. As this value is used in the Libration Tables of the *Connaissance des Temps*, these tables have been utilised. But the Moon's longitude, latitude, mean longitude, and all other quantities required, have been taken from the *Nautical Almanac*. The principal term of the physical libration has also been applied, the co-efficient being $0^\circ.037$ (Franz). The co-longitude of the Sun is 90° (or 450°)—his selenographical longitude. I have considered it better to make the ephemeris continuous without any break at new Moon, as this makes it easier to follow the character of the libration curves.

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1898.	°	°	°	°	°	°
Apr. 16	211.79	+1.51	+4.82	−4.32	6.46	228.1
17	224.01	1.51	4.96	5.34	7.32	222.9
18	236.23	1.50	4.93	6.05	7.80	219.2
19	248.46	1.50	4.72	6.45	8.00	216.2
20	260.69	1.49	4.35	6.51	7.81	213.7
21	272.92	1.49	3.69	6.26	7.26	210.5
22	285.15	1.49	2.85	5.72	6.41	206.5
23	297.38	1.48	1.82	4.92	5.26	200.3
24	309.60	1.48	+0.61	3.92	3.96	188.9
25	321.83	1.48	−0.74	2.75	2.86	164.9
26	334.05	1.47	2.15	1.46	2.60	124.2
27	346.26	+1.47	−3.55	−0.11	3.55	91.8

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1898. Apr.	28	358°47	+1°46	−4°85	+1°26	5°00	75°4
	29	10·67	1·46	5·95	2·59	6·49	66·5
	30	22·88	1·45	6·76	3·83	7·77	60·5
May	1	35·07	1·45	7·20	4·92	8·71	55·7
	2	47·26	1·44	7·19	5·79	9·20	51·2
	3	59·44	1·43	6·70	6·36	9·25	46·5
	4	71·62	1·42	5·75	6·58	8·75	41·2
	5	83·80	1·41	4·40	6·38	7·72	34·6
	6	95·97	1·39	2·77	5·76	6·39	25·7
	7	108·14	1·38	−0·99	4·74	4·83	11·8
	8	120·32	1·37	+0·78	3·40	3·50	347·1
	9	132·50	1·35	2·39	1·83	3·04	307·4
	10	144·69	+1·33	3·76	+0·16	3·76	272·4
	11	156·88	1·32	4·83	−1·48	5·07	253·0
	12	169·09	1·30	5·59	3·00	6·32	241·8
	13	181·30	1·28	6·04	4·31	7·43	234·5
	14	193·52	1·27	6·22	5·36	8·21	229·3
	15	205·75	1·25	6·14	6·10	8·66	225·2
	16	217·98	1·23	5·84	6·52	8·74	221·9
	17	230·21	1·22	5·33	6·62	8·47	218·8
	18	242·45	1·20	4·62	6·39	7·86	215·9
	19	254·69	1·19	3·75	5·87	6·99	212·6
	20	266·94	1·17	2·69	5·10	5·76	207·8
	21	279·18	1·16	1·49	4·10	4·35	199·9
	22	291·42	+1·14	+0·17	2·93	2·93	183·3
	23	303·66	1·13	−1·23	1·64	2·05	143·1
	24	315·90	1·11	2·67	−0·28	2·70	96·0
	25	328·13	1·10	4·06	+1·10	4·22	74·8
	26	340·36	1·08	5·35	2·45	5·88	65·4
	27	352·59	1·07	6·45	3·70	7·42	60·2
	28	4·81	1·05	7·28	4·82	8·74	56·5
	29	17·02	1·03	7·73	5·73	9·59	53·5
	30	29·23	1·01	7·77	6·37	10·02	50·7
	31	41·44	0·99	7·34	6·69	9·91	47·6
June	1	53·63	0·97	6·42	6·62	9·20	44·1
	2	65·82	+0·95	−5·06	+6·13	7·97	39·5

Greenwich Noon.		Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration. Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.
1898.		°	°	°	°	°	°
June	3	78·01	+0·92	−3·34	+5·23	6·22	32·6
	4	90·19	0·90	−1·42	3·94	4·18	19·8
	5	102·38	0·87	+0·58	2·38	2·45	346·3
	6	114·56	0·85	2·47	+0·65	2·54	284·7
	7	126·75	0·82	4·13	−1·10	4·25	255·1
	8	138·95	0·79	5·47	2·75	6·13	243·3
	9	151·15	0·77	6·44	4·18	7·66	237·0
	10	163·36	0·74	7·03	5·32	8·79	232·9
	11	175·58	0·72	7·24	6·14	9·48	229·7
	12	187·81	0·69	7·11	6·62	9·74	227·0
	13	200·04	0·67	6·67	6·76	9·46	224·6
	14	212·27	0·64	5·98	6·57	8·87	222·3
	15	224·52	+0·62	5·06	6·09	7·92	219·7
	16	236·76	0·60	3·97	5·34	6·67	216·6
	17	249·01	0·58	2·74	4·36	5·14	212·1
	18	261·26	0·56	1·41	3·20	3·49	203·8
	19	273·51	0·53	+0·01	1·91	1·91	180·3
	20	285·75	0·51	−1·41	−0·53	1·51	110·6
	21	298·00	+0·49	2·81	+0·87	2·95	72·8
	22	310·25	0·47	4·14	2·24	4·72	61·6
	23	322·49	0·45	5·35	3·53	6·42	56·6
	24	334·73	0·42	6·37	4·68	7·90	53·7
	25	346·97	0·40	7·14	5·63	9·07	51·7
	26	359·20	0·37	7·59	6·34	9·87	50·1
	27	11·42	0·35	7·67	6·73	10·20	48·7
	28	23·64	0·32	7·34	6·78	9·98	47·3
	29	35·85	0·30	6·58	6·44	9·21	45·6
	30	48·05	0·27	5·39	5·70	7·87	43·4
July	1	60·25	0·24	3·83	4·56	5·97	40·0
	2	72·44	0·21	2·00	3·09	3·68	32·9
	3	84·63	+0·18	−0·04	+1·39	1·39	1·6
	4	96·81	0·15	+1·93	−0·41	1·97	258·0
	5	109·00	0·12	3·74	2·17	4·34	239·9
	6	121·19	0·09	5·29	3·75	6·51	234·7
	7	133·39	0·06	6·47	5·04	8·22	232·1
	8	145·60	+0·03	+7·23	−6·00	9·40	230·3

Greenwich Noon.		Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1898.		°	°	°	°	°	°
July	9	157·81	0·00	+7·57	−6·59	10·03	229·0
	10	170·03	−0·03	7·49	6·82	10·11	227·7
	11	182·25	0·06	7·05	6·70	9·73	226·5
	12	194·48	0·08	6·28	6·28	8·85	225·0
	13	206·71	0·11	5·26	5·56	7·67	223·4
	14	218·95	0·13	4·05	4·62	6·14	221·3
	15	231·20	−0·16	2·72	3·50	4·44	217·8
	16	243·44	0·18	+1·31	2·22	2·58	210·5
	17	255·69	0·21	−0·11	−0·85	0·86	172·6
	18	267·94	0·23	1·49	+0·55	1·59	69·7
	19	280·19	0·25	2·80	1·94	3·42	55·3
	20	292·44	0·27	3·98	3·26	5·13	50·7
	21	304·69	0·30	5·00	4·45	6·70	48·3
	22	316·93	0·32	5·84	5·45	8·00	47·0
	23	329·17	0·34	6·44	6·20	8·95	46·1
	24	341·41	0·37	6·78	6·66	9·49	45·5
	25	353·64	0·39	6·82	6·80	9·62	45·1
	26	5·86	0·42	6·54	6·56	9·25	44·9
	27	18·08	−0·45	5·92	5·95	8·39	44·9
	28	30·29	0·47	4·97	4·97	7·01	45·0
	29	42·49	0·50	3·70	3·66	5·22	45·3
	30	54·69	0·53	2·17	2·08	3·02	46·2
	31	66·88	0·56	−0·46	+0·34	0·57	53·5
Aug.	1	79·06	0·59	+1·33	−1·43	1·96	222·9
	2	91·24	0·62	3·06	3·10	4·34	224·6
	3	103·42	0·65	4·62	4·53	6·47	225·6
	4	115·61	0·67	5·88	5·64	8·17	226·2
	5	127·81	0·70	6·75	6·38	9·31	226·6
	6	140·01	0·72	7·20	6·72	9·86	227·0
	7	152·21	0·75	7·21	6·70	9·88	227·1
	8	164·42	−0·77	6·80	6·35	9·32	227·0
	9	176·63	0·79	6·03	5·70	8·32	226·6
	10	188·85	0·82	4·99	4·81	6·94	226·0
	11	201·08	0·84	3·74	3·73	5·27	225·1
	12	213·31	0·86	2·36	2·50	3·42	223·3
	13	225·54	−0·87	+0·94	−1·16	1·50	219·0

Greenwich Noon.		Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.
1898.		°	°	°	°	°	°
Aug.	14	237·78	−0·89	−0·46	+0·23	0·52	63·4
	15	250·02	0·91	1·76	1·62	2·39	47·4
	16	262·26	0·93	2·91	2·95	4·13	44·6
	17	274·50	0·95	3·88	4·16	5·70	43·0
	18	286·74	0·97	4·64	5·19	6·95	41·8
	19	298·99	0·98	5·18	5·99	7·91	40·9
	20	311·22	−1·00	5·49	6·50	8·51	40·2
	21	323·46	1·02	5·57	6·68	8·68	39·8
	22	335·69	1·04	5·43	6·51	8·46	39·8
	23	347·92	1·06	5·07	5·98	7·83	40·3
	24	0·13	1·08	4·49	5·10	6·78	41·3
	25	12·34	1·10	3·70	3·91	5·40	43·4
	26	24·54	−1·12	2·70	2·46	3·65	47·7
	27	36·74	1·15	1·52	+0·83	1·73	61·4
	28	48·92	1·17	−0·18	−0·86	0·88	168·1
	29	61·10	1·19	+1·25	2·51	2·81	206·5
	30	73·28	1·21	2·68	3·99	4·79	213·9
	31	85·45	1·23	4·02	5·19	6·59	217·8
Sept.	1	97·63	1·25	5·14	6·05	7·93	220·4
	2	109·80	1·26	5·95	6·52	8·80	222·4
	3	121·98	1·28	6·38	6·61	9·19	224·0
	4	134·17	1·30	6·40	6·34	9·02	225·3
	5	146·36	1·31	6·02	5·76	8·31	226·3
	6	158·55	1·32	5·27	4·92	7·22	227·0
	7	170·75	−1·33	4·22	3·88	5·74	227·4
	8	182·95	1·34	2·96	2·68	4·00	227·9
	9	195·16	1·35	1·58	1·37	2·09	229·1
	10	207·38	1·36	+0·16	−0·01	0·16	266·4
	11	219·59	1·37	−1·19	+1·35	1·80	41·4
	12	231·81	1·38	2·40	2·67	3·60	42·0
	13	244·04	1·39	3·40	3·89	5·17	41·2
	14	256·27	1·40	4·14	4·94	6·47	40·0
	15	268·50	1·41	4·61	5·77	7·39	38·6
	16	280·73	1·41	4·80	6·33	7·98	37·2
	17	292·96	1·42	4·72	6·56	8·07	35·8
	18	305·19	−1·43	−4·42	+6·43	7·78	34·5

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1898.	°	°	°	°	°	°
Sept. 19	317·41	−1·44	−3·95	+5·94	7·13	33·6
20	329·63	1·45	3·33	5·10	6·12	33·2
21	341·84	1·46	2·62	3·95	4·74	33·5
22	354·05	1·47	1·82	2·56	3·15	35·4
23	6·25	1·48	0·96	+1·00	1·39	43·8
24	18·43	1·49	−0·02	−0·62	0·62	178·1
25	30·61	1·50	+0·98	2·21	2·41	203·9
26	42·79	1·51	2·01	3·67	4·18	208·7
27	54·96	1·51	3·03	4·89	5·77	211·8
28	67·12	1·52	3·97	5·80	7·02	214·4
29	79·28	1·52	4·76	6·35	7·94	216·9
30	91·44	1·53	5·31	6·53	8·42	219·1
Oct. 1	103·60	−1·53	5·55	6·34	8·43	221·2
2	115·77	1·53	5·45	5·82	7·97	223·1
3	127·93	1·53	4·99	5·02	7·08	224·8
4	140·10	1·53	4·19	4·00	5·78	226·3
5	152·28	1·53	3·14	2·81	4·21	228·2
6	164·46	1·53	1·87	1·52	2·41	230·9
7	176·64	1·52	+0·48	−0·18	0·51	249·4
8	188·83	1·52	−0·92	+1·18	1·50	38·2
9	201·03	1·52	2·26	2·49	3·36	42·2
10	213·22	1·51	3·41	3·70	5·03	42·7
11	225·43	1·51	4·32	4·77	6·44	42·2
12	237·64	1·50	4·91	5·63	7·49	41·1
13	249·85	−1·50	5·14	6·23	8·10	39·5
14	262·06	1·49	5·03	6·52	8·22	37·7
15	274·28	1·49	4·58	6·45	7·93	35·4
16	286·49	1·48	3·87	6·00	7·14	32·8
17	298·71	1·48	2·96	5·18	5·96	29·7
18	310·92	1·48	1·95	4·04	4·48	25·8
19	323·13	1·47	−0·92	2·64	2·80	19·2
20	335·32	1·47	+0·10	+1·07	1·07	354·7
21	347·51	1·47	1·06	−0·56	1·20	242·1
22	359·70	1·46	1·96	2·14	2·91	222·5
23	11·87	1·46	2·78	3·59	4·52	217·7
24	24·04	−1·45	+3·51	−4·81	5·96	216·1

Greenwich Noon.	Selenographical Colong. of the Sun.	Selenographical Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Geocentric Libration Lat. of the Earth.	Combined Amount.	Direction.
1898.	°	°	°	°	°	°
Oct. 25	36·20	−1·44	+4·15	−5·74	7·06	215·9
26	48·35	1·43	4·68	6·34	7·86	216·4
27	60·51	1·42	5·04	6·56	8·27	217·5
28	72·65	1·41	5·20	6·43	8·29	219·0
29	84·80	1·40	5·11	5·96	7·85	220·6
30	96·94	1·39	4·75	5·20	7·04	222·4
31	109·09	−1·37	4·11	4·19	5·87	224·5
Nov. 1	121·24	1·36	3·20	3·01	4·38	226·7
2	133·39	1·34	2·07	1·71	2·69	230·4
3	145·55	1·32	+0·76	−0·35	0·84	245·3
4	157·71	1·31	−0·64	+1·02	1·20	32·1
5	169·88	1·29	2·06	2·35	3·13	41·3
6	182·05	1·27	3·39	3·58	4·94	43·4
7	194·22	1·26	4·55	4·67	6·49	44·2
8	206·40	1·24	5·45	5·57	7·80	44·4
9	218·59	1·22	6·00	6·23	8·66	43·9
10	230·78	1·20	6·16	6·59	9·03	43·1
11	242·97	1·19	5·90	6·61	8·86	41·8
12	255·17	−1·17	5·23	6·24	8·17	40·0
13	267·37	1·15	4·21	5·49	6·92	37·5
14	279·58	1·14	2·92	4·38	5·26	33·7
15	291·78	1·12	1·49	2·97	3·33	26·7
16	303·98	1·11	−0·02	+1·35	1·35	0·8
17	316·17	1·09	+1·40	−0·35	1·44	256·0
18	328·36	1·07	2·66	2·02	3·35	232·8
19	340·54	1·06	3·75	3·43	5·06	227·6
20	352·71	1·04	4·62	4·81	6·69	223·9
21	4·87	1·02	5·27	5·79	7·82	222·3
22	17·03	1·00	5·70	6·42	8·60	221·6
23	29·18	0·98	5·90	6·69	8·90	221·4
24	41·33	−0·96	5·89	6·60	8·84	221·7
25	53·47	0·93	5·65	6·18	8·34	222·4
26	65·60	0·91	5·18	5·46	7·53	223·5
27	77·74	0·88	4·50	4·48	6·34	225·1
28	89·88	0·86	3·61	3·31	4·91	227·5
29	102·01	−0·83	+2·53	−2·00	3·21	231·7

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat. of the Sun.	Geocentric Libration Sel. Long. of the Earth.	Lat. of the Earth.	Combined Amount.	Direction.
1898.	°	°	°	°	°	°
Nov. 30	114·15	−0·80	+1·29	−0·62	1·43	244·3
Dec. 1	126·29	0·77	−0·07	+0·79	0·79	5·1
2	138·43	0·75	1·49	2·15	2·62	34·7
3	150·58	0·72	2·91	3·42	4·48	40·4
4	162·73	0·69	4·24	4·55	6·23	43·0
5	174·88	0·67	5·42	5·49	7·69	44·6
6	187·04	−0·64	6·35	6·21	8·89	45·7
7	199·20	0·61	6·97	6·65	9·62	46·3
8	211·38	0·58	7·19	6·78	9·85	46·7
9	223·55	0·56	6·99	6·55	9·58	46·9
10	235·73	0·54	6·33	5·94	8·67	46·8
11	247·92	0·51	5·25	4·94	7·19	46·7
12	260·12	0·49	3·80	3·61	5·24	46·5
13	272·31	0·46	2·10	2·00	2·90	46·4
14	284·50	0·44	−0·27	+0·24	0·36	48·4
15	296·70	0·42	+1·55	−1·54	2·19	225·2
16	308·89	0·39	3·24	3·20	4·57	225·3
17	321·07	0·37	4·69	4·61	6·57	225·5
18	333·24	−0·35	5·82	5·71	8·15	225·6
19	345·41	0·32	6·61	6·44	9·25	225·7
20	357·57	0·29	7·04	6·78	9·79	226·1
21	9·73	0·27	7·12	6·75	9·83	226·6
22	21·87	0·24	6·88	6·38	9·36	227·2
23	34·01	0·20	6·35	5·71	8·57	228·0
24	46·15	0·17	5·59	4·77	7·38	229·5
25	58·29	0·14	4·62	3·63	5·87	231·8
26	70·42	0·11	3·48	2·34	4·18	236·1
27	82·55	0·08	2·22	−0·96	2·42	246·6
28	94·68	0·05	+0·87	+0·45	0·98	297·4
29	106·81	−0·02	−0·53	1·84	1·91	16·1
30	118·94	+0·02	1·94	3·15	3·69	31·6
31	131·08	+0·05	3·30	4·32	5·44	37·6
1899. Jan. 1	143·21	+0·08	−4·58	+5·32	7·02	40·7

7 Vanbrugh Park Road, Blackheath, S.E.:
1898 *March* 11.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. APRIL 6, 1898. No. 6

Sir R. S. BALL, M.A., LL.D., F.R.S., President, in the Chair.

Captain Vernon L. D. Broughton, Hillside, Godstone, Surrey;
Charles Friswell, 34 Madeley Road, Ealing, W.;
Professor C. J. Joly, M.A., Royal Astronomer of Ireland, The Observatory, Dunsink, co. Dublin; and
William Ritchie, 75 Morningside Road, Edinburgh,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Henry Ellis, Little Heath, Potter's Bar (proposed by J. G. Petrie);
Peter Matthews, Solicitor, 102 Fenchurch Street, E.C., and 65 Gordon Mansions, W. (proposed by Thomas Mackenzie);
Captain P. B. Molesworth, R.A., Trincomali, Ceylon (proposed by E. W. Maunder);
W. J. Reynolds, 61 Fairholt Road, Stamford Hill, N. (proposed by F. W. Dyson); and
William Edward Sparkes, Stockbroker, 5 Roker Terrace, Sunderland (proposed by Cuthbert Hutchinson).

Sixty-eight presents were announced as having been received since the last meeting, including amongst others :—

Ph. Fauth, Beobachtungen der Planeten Jupiter und Mars, 1896–97, III. ; J. N. Krieger, Mond-Atlas, Band I. ; A. Stanley Williams, Catalogue of the magnitudes of 1081 southern stars, presented by the authors ; Paris Observatory, Atlas photographique de la lune, par MM. Lœwy et Puiseux, fasc. 2 ; Potsdam Observatory, Publicationen, Band XI. ; presented by the Observatories ; Set of transparencies from negatives of the total solar eclipse of 1898 January 22, presented by the Astronomer Royal ; Photographs of the total solar eclipse of 1898 January 22, presented by C. Thwaites.

The Spectrum of o Ceti as photographed at Stonyhurst College Observatory. By the Rev. Walter Sidgreaves, S.J.

The series of photographs of the spectrum of *o Ceti*, obtained during the recent favourable period of its maximum light, consists of 20 plates, on 15 nights, beginning with 1897 November 18, and ending on 1898 February 5. Six of these were taken in November on the dates 18, 23, 24, 28, 29 ; twelve in December on dates 1, 2, 11, 15, 19, 24, 25, 28, 30 ; one on January 7, and one on February 5.

All the photographs are upon Edwards' Isochromatic plates, excepting the one of December 30, which is on a Mawson plate. All are good photographs ; but the accompanying tables of wave-lengths (p. 348), and the map of the spectrum (plate 3),* are formed upon one plate, that of November 29, supplemented, in the violet, by the Mawson plate of December 30. These were judged to be the best of the series. Eleven other plates were selected for measures of the sharp edges of the bands, to serve as a check upon the scale readings used for the map and tables.

The map has been executed with the greatest care, to represent as closely as possible the relative radiation-energy of each part of the spectrum as it arrives upon the plate, allowance being made everywhere for the sensibility curve of Edwards' Isochromatic plate ; and this curve has been estimated upon the supposition of uniform energy at all the parts of the spectrum of *a Tauri*.

The spectrum has apparently remained substantially constant during the period of observation. But a marked change in the relative intensities of the yellow-green and the blue radiations

* Two photographic mounts presented to the Society with this Paper are reproduced as Plate 1 and Plate 2. They are direct enlargements from the original negatives, widened by a cylindrical lens. All the lines have been verified by comparison with enlargements made without the cylindrical lens. They do not show all the details of the original negatives.

appears to have taken place during the cloudy week between December 2 and December 11. On all the preceding dates the photographs show the maximum silver deposit in the blue region of the spectrum; and on all the subsequent dates the yellow-green radiation has produced a stronger impression. This alteration is illustrated by three enlargements on Plate 1.

Of the hydrogen lines H_ϵ is still absent, lost, or much weakened in the calcium absorption; and H_β may be visible as a division of the band which begins at λ 4842. This division of the band is at 4861, the position of H_β, and is, on this account only, entered in Table I. as a bright line, but without an estimated intensity, the brightness being less than that of the continuous spectrum. But it is not easy to reconcile the comparatively weak absorption at this part of the band in *Mira* with its supposed absorbing action on the very energetic radiation of H_β. The hydrogen tubes in the laboratory give H_β very greatly over-exposed, when the time has been long enough to give H_δ the precise character of the line on the star plates. And we have to take into consideration the extraordinary brilliancy of the two lines H_δ and H_γ in the star's spectrum: it is too great to be shown on a drawing, or to be safely expressed by a number representing relative intensity. These lines are so strong on the negatives that it is not easy to darken them on a positive enlargement by over-exposure; and they remain perfectly clear, when the over-exposure has been long enough to darken greatly all the other bright zones of the spectrum. It seems more probable that *o Ceti* shows a condition of hydrogen radiance not yet met with in the laboratory, in which H_ϵ and H_β have fallen out of the spectrum.

Professor Keeler's remark on the spectrum of *α Herculis* is applicable to the spectrum of *o Ceti*. He says,* "It is impossible to avoid the conclusion that the edges of the zones bordering on the dark bands are bright—much brighter, that is, than the average continuous spectrum." These zones are given in Table I. according to our estimate of the relative intensities representing continuous spectrum.

The band having its sharp edge at λ 5162 has been the subject of careful examination. The question at the beginning was whether we had to deal with a bright fluting shading towards the violet or not. Our judgment of the brightness of this region, referred to the continuous spectrum as zero, is given in Table I. in favour of a possible bright band. But there is an absorption band shading from the same position, 5162, in the opposite direction. Of this there can be but little doubt; it is impossible, without it, to interpret the photographs consistently with the sensibility curve of the isochromatic plate, unless we suppose the green radiation to be less energetic in this class of stars than in stars nearer to the solar type. The two bands, one bright and

* *Astronomical Journal*, vi. 5, p. 424.

fading towards the blue, the other dark and shading towards the red, cannot well stand together with a common termination ; and there is no appearance of overlapping, which ought to manifest itself as a pale separating band. For this reason our photographs seem to be against the carbon origin of the brightness at λ 5162.

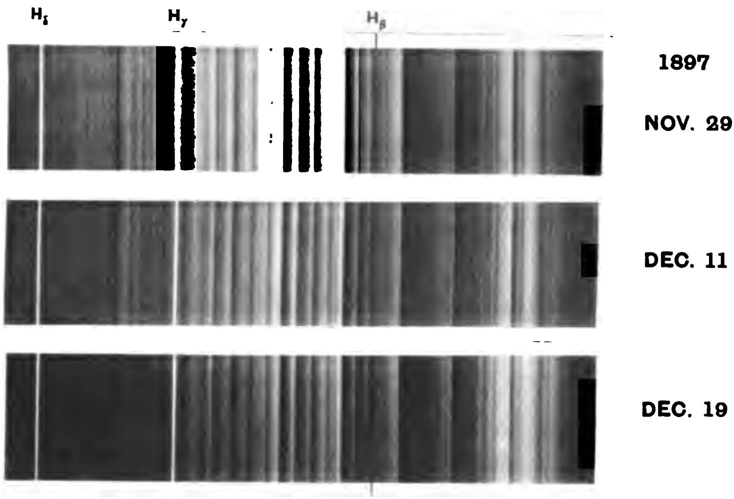
In Plate 2 the position of *o Ceti* in Secchi's third type, in gradations towards the second type, is shown by comparison with the spectra of other stars, in the order *α Herculis*, *β Pegasi*, *η Geminorum*, *α Orionis*, *β Andromedæ*, and *α Tauri*. It is more remote from the solar spectrum than *α Herculis*. Its bands or flutings are stronger, as noted by Lockyer in 1893, but the chief differences between the two spectra, omitting the hydrogen lines, are the more decided fluting character of the bands of *o Ceti* on the violet side of λ 471, and the remarkably strong radiation of *α Herculis* between $\lambda\lambda$ 4227 and 4458.

The line spectrum of *o Ceti* places the star in Lockyer's subdivision *α* of Table C. He finds, besides hydrogen, iron, manganese, calcium, chromium, cobalt, titanium, and strontium, common to them all,* and the calcium lines intensified, as compared with those in the solar type of spectra. The strong absorption line† in the photographs of Plate 1, between H_δ and H_γ is at λ 4227, and is therefore probably the strong calcium line at 4227. Another strong line on the more refrangible side of H_δ, very distinct on the negatives, is at λ 4077, the position of one of the strongest strontium lines. Other lines are equally precise coincidences with known strong lines in the arc spectra of strontium and iron. In Table II. of wave-lengths a comparison column is added for the spectra of iron, and other metals in which all and only those lines are entered which have the note of full intensity in Watts' Index of Spectra, within the limits of the photograph. The brackets in the column of band numbers show the widths of the bands, and enclose the superimposed lines. A band terminates with a spectral line when the terminating wave-length is not enclosed in a round bracket. The round bracket signifies the termination only, and not a line. A square bracket covering a number of wave-lengths within a band signifies that these would not be seen as separate lines without careful examination of the original plates.

The grouping of the bands is not marked in the table of wave-lengths. But it is very apparent on the photographs : they run in quartets, with deepest absorption on the violet sides, and general shading towards the red sides. These appear as single bands in the smaller spectrum given by a half prism and short focus camera.

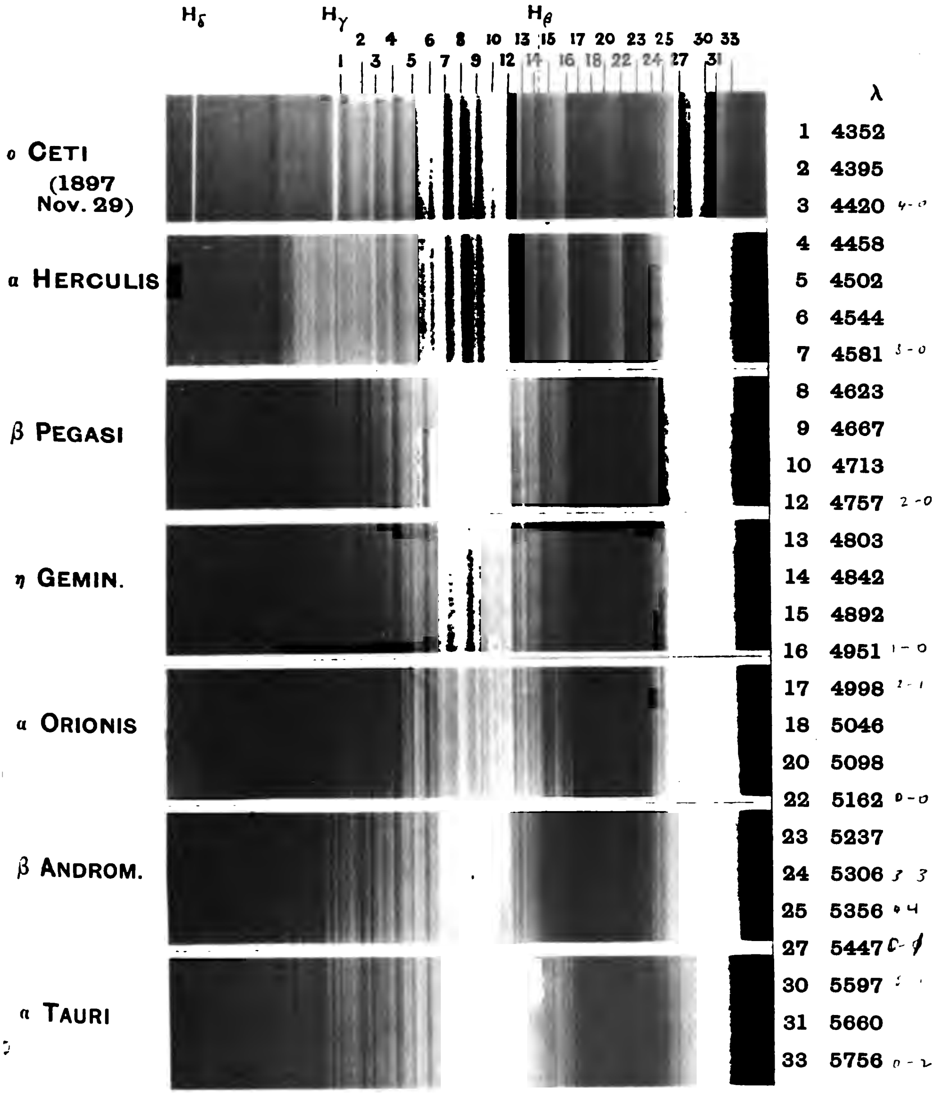
* *Phil. Trans.* vol. clxxxiv. p. 705.

† This line appears on all the photographs of Plate 2, but not with its proper strength, this end of the spectrum having been sacrificed in the original negatives in order to bring out the lines in the more sensitive part of the plate. It shows as the strongest absorption line in the spectrum of *α Tauri* on plates of long exposure.

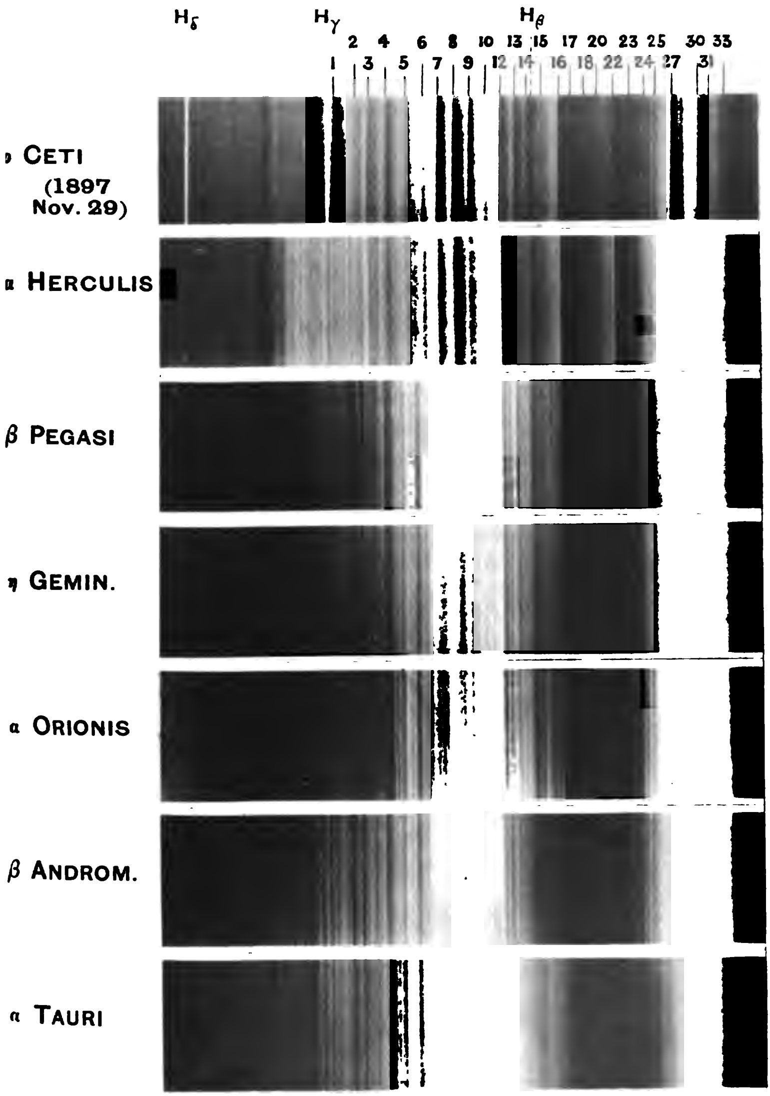


SPECTRUM OF o CETI, SHOWING A PROGRESSIVE CHANGE IN THE RELATIVE RADIATIONS OF THE BLUE AND YELLOW REGIONS, STONYHURST COLLEGE OBSERVATORY

Spottiswoode & C.



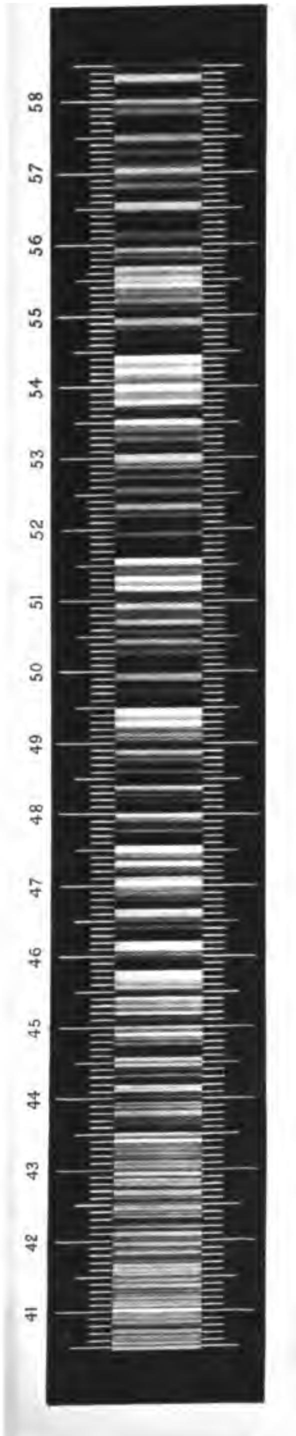
PROGRESSIVE STELLAR SPECTRA BETWEEN SECCHI'S
3RD AND 2ND TYPES
STONYHURST COLLEGE OBSERVATORY



	λ	
1	4352	
2	4395	
3	4420	4-0
4	4458	
5	4502	
6	4544	
7	4581	3-0
8	4623	
9	4667	
10	4713	
12	4757	2-0
13	4803	
14	4842	
15	4892	
16	4951	1-0
17	4998	2 1
18	5046	
20	5098	
22	5162	0-0
23	5237	
24	5306	3 3
25	5356	4 4
27	5447	5 4
30	5597	
31	5660	
33	5756	0-2

PROGRESSIVE STELLAR SPECTRA BETWEEN SECCHI'S
3RD AND 2ND TYPES
STONYHURST COLLEGE OBSERVATORY

Spottiswoode &



SPECTRUM OF o CETI, DRAWN FROM A PHOTOGRAPH TAKEN ON NOVEMBER 29, 1897,
AT
STONYHURST COLLEGE OBSERVATORY

A close examination of the enlarged photographs of Plate 2 shows a marked difference either in the real positions of the sharp edges of the bands, or in the lengths of the photographed spectra. In the latter supposition *o Ceti* shows a shorter spectrum, and *a Herculis* a longer one than *β Pegasi* or *a Orionis.* These differences are not owing to inexactness of enlargement. They were shown on the original plates, by the micrometer, before the enlargements were made. It is impossible to escape the conclusion that they are owing to some instrumental defect; but so far the cause is not clear. Something may be set down—1st, to the relatively great flexure of the telescope tube, owing to the form of mounting necessary for the adaptation of the large object glass; 2nd, to imperfect centering of the light rays through the prism; 3rd, to micrometer imperfections; and, 4th, to differences of temperature. But the maximum effects of these have been measured, and found to be insufficient, when taken together, to account for the differences. There remains only the photographic effect of longer exposure, corresponding to the widening of a bright line. This would be to increase the length between the fiducial position, H_γ, and the edges of the bands in the green-yellow regions; but that no appreciable effect of this nature can be admitted in the photographs is shown by two exposures on the night of November 23. One of these was by a slow trail corresponding to a long exposure, and the other by a very quick trail. The latter gave a weak photograph with excellent definition, to compare with the strong photograph of the longer exposure; and both exposures were upon the star at the same average altitude, east and west of the meridian. The positions of the bands by both plates were the same.

With these considerations before us we are forced to admit the probability of a real difference between the positions of the strong edges of the bands in *o Ceti* and in *a Herculis*, as compared with the remaining stars of Plate 2. These differences appear in the following table of positions of the edge of Duner's band 5 (No. 27 of our photographs on Plate 2).

	Edge of Band.
o Ceti	5447
β Pegasi	5451
a Orionis	5451
a Herculis	5458

TABLE I.

Bright Lines, and possible Bright Bands, in the spectrum of o Ceti.

	Wave-length.	Intensity.	Remarks.
H_δ	4101	10	Sharp line.
H_γ	4340	10	" "
1	{4566 4580	1	
2	{4608 4622	1	
3	{4700 4756	2	
	4861		Presumably H_β: a faint narrow division in a broad absorption band.
4	{4924 4950	2	
5	{5114 5161	2	
6	{5374 5446	2	

TABLE II.

Absorption Spectrum of o Ceti.

Band Nos.	o Ceti. Wave-lengths.	Intensity and Character.	Strong lines of Iron, &c.	Band Nos.	o Ceti. Wave-lengths.	Intensity and Character.	Strong lines of Iron, &c.
	4052	2			4116	1	
	4059	1 *f*			4123	1 *f*	
	4063	1 *f*	4063 Fe		4128	2	
	4068	2	4071 Fe		4133	2	4131 Fe
	4077	4	4077 Sr		4142	2	4143 Fe
	4082	1			4151	2	
	4088	1			4156	1 *f*	
	4095	1 *f*			4164	1 *f*	4163 Ti
	4098	1 *f*			4169	2	4171 Ti
	*4105	2			4176	3	
	4112	1 *f*			4180	2 *f*	

w = wide line
f = narrow or fine
b = band.

* See bright line spectrum (Table I.)

Band Nos.	o Ceti. Wave-lengths.	Intensity and Character.	Strong lines of Iron, &c.
	4187	2	4187 Fe
	4192	2	4191 Fe
	4199	2	4199 Fe
	4205	2	4202 Fe
	4215	4	4215 Sr
	4222	4 *f*	
	4227	10 *w*	4227 Ca, Mn
	4231	4 *f*	
	4236	2	4235 Mn
	4242	2	
	4247	1 *f*	
	4251	2 *f*	4250 Fe 4254 Cr
	4256	3	
	4262	2	4260 Fe
	4273	3 *w*	4271 Fe 4272 Mn 4275 Cr
	4282	1	4281 Thorium
	4290	2	4289 Cr
	4299	2	4299 Fe Ti
	4302	1 *f*	4302 Ca 4305 Sr
	4308	1	4307 Fe
	4315	2	4315 Fe
	4320	1	
	4326	1	4325 Fe Mn
	4333	1	
	4337	1	4337 Fe 4338 Ti
	*4345	2	
	(4352)	7	
	4354	7	
	4359	6	4358 Hg
1	4363	2 *f*	
	4369	3	
	4373	3	
	(4375)	2	4379 Vanadium 4382 Thorium

Band Nos.	o Ceti. Wave-lengths.	Intensity and Character.	Strong lines of Iron, &c.
	4385	3	4383 Fe 4384 Vanadium
	4392	2	4393 Ti Tho
	(4395)	5	
2	4397	5 *w*	
	4407	5 *w*	4405 Fe 4408 Vanadium
	(4409)	5	
	4415	1 *f*	4415 Fe Mn
	(4420)	4	
	4421	4 *f*	
	4424	6 *w*	4425 Ca
3	4429	4	4427 Ti
	4435	5 *w*	4435 Ca 4442 Fe
	4442	4	4443 Ti 4436 Mn
	4450	2	4447 Fe 4451 Mn
	(4458)	6	4454 Ca 4455 Mn
	4459	6 *f*	4457 Mn 4461 Mn
	4463	7 *w*	4464 Mn
4	4470	6	4469 Ti 4470 Mn
	4474	5	4472 Mn 4475 Fe
	4480	3	4482 Fe
	4486	2	
			4489 Mn
	4494	2 *f*	4494 Fe
	4496	2 *f*	4498 Mn
	(4502)	6	4501 Ti Mn
	4504	6	
5	4506	6	
	4514	5	
	(4517)	5	
	4523	2 *f*	4524 Sn
	4526	2 *f*	4526 Ti 4528 Fe
	4533	2 *f*	

w = wide line. *f* = narrow or fine. *b* = band.

* See bright line spectrum (Table I.)

Band Nos.	o Ceti. Wave-lengths.	o Ceti. Intensity and Character.	Strong lines of Iron, &c.
	4537	1 *f*	4536 Ti
6	(4544)	5	
	4546	5 *w*	4549 Ti
	4551	5	
	4560	2	
	4565	1	
	4571	1 *f*	4572 Ti
	4575	1 *f*	
7	(4581)*	10	
	4583	10 *w*	
	4589	10 *w*	
	4599	4	4602 Fe
	4605	4	
	(4607)	4	4607 Sr
	4613	1 *f*	
	4617	1 *f*	
8	* (4623)	8	
	4626	8 *b*	
	4635	7 *w*	
	4646	5 *w*	4639 Ti
	4653	3	4654 Fe 4656 Ti
	4660	1 *f*	
9	(4667)	9	4666 Fe
	4670	9 *w*	
	4675	8	4678 Fe 4679 Zn
	4683	3	
	4692	2	4691 Fe
	4697	2	
	(4699)	2	
	4708	1 *f*	4707 Fe 4709 Mn
10	(4713)	4	
	4715	4 *w*	
	4723	3	4721 Zn
	(4725)	3	4726 Mn

Band Nos.	o Ceti. Wave-lengths.	o Ceti. Intensity and Character.	Strong lines of Iron, &c.
11	(4735)	3	
	4738	3	4736 Fe
	4744	2	
	4750	1 *f*	4753 Mn
12	(4757)*	10	4757 Ti
	4759	10	4759 Ti 4761 Mn
	4765	10	4765 Mn
	4771	10	
	4782	6 *w*	4779 Co 4782 Mn
	4789	4	
	4794	2	4792 Co
13	(4803)	6	
	4804	6	4804 Ti
	4808	10	4809 Zn
	4811	9	
	4824	4	4814 Co 4823 La Di Mn
	4831	4	
	(4834)	2	
14	(4842)	8	4840 Co
	4843	8	
	4849	9 *w*	
	4855	8	4855 Ni 4859 Fe
	4869*	6 *b*	4866 Ni 4871 Fe
	4881	4	4873 Ni 4877 Fe
	(4884)	4	4885 Ti
15	(4892)	3	4891 Fe
	4897†	6 *b*	4899 La Di
	4908	2	4911 Zn
	4917	3	4919 Fe
	4922	2	4920 La Di 4921 La Di
	4934	1	
	4937	1	

w = wide line. *f* = narrow or fine. *b* = band.

* See bright line spectrum (Table I.) † Probably a triplet.

Band Nos.	o Ceti. Wave-lengths.	Intensity and Character.	Strong lines of Iron, &c.
16	(4951)*	10	
	4954	10 *b*	4957 Fe
	4963	10 *b*	
	4981	8 *b*	4981 Ti
	(4986)	8	4990 Ti
17	(4998)	9	4999 Ti
	5003	9 *b*	5001 Fe 5006 Fe
	5018	7 *b*	5007 Ti 5013 Ti
	5035	5 *b*	5036 Ti
	(5039)	5	
18	(5046)	6	
	5050	6 *b*	5049 Fe
	5062	6 *b*	5064 Ti
	(5066)	6	5068 Fe
19	(5074)	3	
	5077	4 *w*	
	5085	4 *w*	
	(5088)	3	
20	(5098)	4	
	5099	4	
	5107	5 *w*	
	5112	3	5120 Ti
	5124	2 *w*	5129 Ti
21	(5135)	3	
	5139	3 *w*	5139 Fe
	5148	3 *w*	
	(5151)	3	

Band Nos.	o Ceti. Wave-lengths.	Intensity and Character.	Strong lines of Iron, &c.
22	(5162)*	10	
	5165	10 *w*	5167 Fe Mg
	5171	10 *w*	5171 Fe 5172 Mg
	5185	8 *b*	5183 Mg 5191 Fe
	5201	8 *b*	5193 Ti 5204 Cr 5206 Cr
	5212	8 *b*	5208 Cr 5210 Ti
	5224	4 *w*	5223 Ti 5226 Fe
	(5227)	4	5232 Fe
23	(5237)	8	5238 Sr
	5244†	8 *b*	
	5265†	8 *b*	5265 Fe 5268 Fe 5269 Fe
	5280	7 *b*	5283 Fe Ti 5297 Ti
	5292	3	5301 Fe 5327 Fe
24	(5306)	7	
	5310	7 *b*	
	5320	7 *b*	
	5335	4 *b*	5337 Ti
	5344	3	
	(5346)	3	
25	(5356)	6	
	5358	6	
	5364	8 *w*	
	5371	5	5371 Fe
	(5373)	5	

w = wide line.
f = narrow or fine.
b = band.

* See bright line spectrum (Table I.)
† Probably a double.

	o Ceti.		
Band Nos.	Wave-lengths.	Intensity and Character.	Strong lines of Iron, &c.
	5385	1	
	5391	1	
26	(5406)	2	5405 Fe
	5409	2 *w*	
	5416	1	5415 Fe
	(5418)	1	5423
	5431	1 *w*	5428 Fe 5433 Fe
27	(5447)*	10	5446 Fe
	5450	10 *b*	
	5460	10 *b*	5455 Fe 5460 Hg
	5473	7 *w*	5475 } Uranium 5477 } 5480 Sr
	5479	7 *w*	5479 Uranium
	5486	3	5482 Uranium
28	(5498)	5	5494 Uranium
	5499	5	
	5503	9 *w*	
	5514	5 *w*	5512 Ti 5513 Ti
	5527	3 *w*	5527 Uranium
	5536	3 *w*	
	(5539)	3	
	5548	1	
	5559	2 *w*	5562 Sn
29	(5570)	7	
	5574	7 *b*	5571 Fe
	5587	4 *w*	5586 Fe 5587 Ca
	(5589)	4	5588 Sn

	o Ceti.		
Band Nos.	Wave-lengths.	Intensity and Character.	Strong lines of Iron, &c.
30	(5597)	8	5597 Fe
	5603	8 *b*	5602 Fe 5615 Fe
	5626 †	9 *b*	
	5642	7 *b*	5643 Ti
	(5647)	7	5658 Fe
31	(5660)	7	
	5661	7	5662 Ti
	5667	8 *w*	
	5674	7	5674 Ti
	5689	5 *w*	
	5696	3	
	(5698)	3	
32	(5709)	3	
	5710	3	5708 Fe
	5720	5 *b*	
	5739	4 *b*	
	(5745)	4	
33	(5756)	8	
	5761	8 *b*	5768 Hg
	5771	8 *b*	
	5792	3 *b*	5790 Hg
	(5796)	3	5798 Sn
34	(5804)	8	
	5808	8 *b*	
	5821	8 *b*	
	(5827)	8	
35	(5840)	8	
	5845	8 *b*	
	5857	8 *b*	
	(5862)	8	

w = wide line.
f = narrow or fine.
b = band.

* See bright line spectrum (Table I.)
† Probably a double.

After this paper was presented to the Society, a method of reproducing stellar spectra from orthochromatic plates, corrected for the sensibility curve of the plate, was suggested by Mr. W. McKeon, Assistant at this Observatory. It promises well enough to be recommended to other workers in stellar spectrography.

The orthochromatic negative is screened, during the enlarging exposure, by a reversal of the *continuous* spectrum of the negative. The screen is obtained as a glass positive of the orthochromatic continuous spectrum of a coal-gas light filtered through a blue glass during part of the exposure.

Theoretically the perfect screen is the positive of the *star's* continuous spectrum, and of the same density as the stellar negative. It is therefore necessary to have in readiness a large number of screens varying both in the relative intensities of the blue and yellow impressions and in general density. When these are prepared and labelled, it is not difficult to select the suitable screen for producing an enlargement of fairly uniform intensity.

Comparison of the Forthcoming Greenwich Ten-Year Catalogue for 1890, *with certain Fundamental Catalogues.*

(*Communicated by the Astronomer Royal.*)

In the preparation of the Greenwich Ten-Year Catalogue for 1890, the reduction of the fundamental stars has been completed in advance of the rest of the catalogue, as Dr. Auwers wished to be furnished with the results for use in the preparation of his New Fundamental Catalogue. The positions for 1890·0, given by the Greenwich Observations 1887–1896, have been obtained for the fundamental stars in the two catalogues of stars contained in the *Berliner Jahrbuch*, and, as a check on the numerical accuracy of the reductions, a comparison of the Greenwich results has been made with the catalogues of fundamental stars given in the *Berliner Jahrbuch* (Auwers), *American Ephemeris* (Newcomb and Boss), and Professor Newcomb's "New Fundamental Catalogue" adopted in the *Nautical Almanac* for 1901, and at the same time the systematic differences have been obtained. As the Greenwich Catalogue will probably not be completed for a year, it is of interest to give briefly the result of these comparisons.

In the New Greenwich Ten-Year Catalogue the methods of reduction are similar to those of the Ten-Year Catalogue (1880). Although the observations of the Sun showed a correction to the equinox, the changes in the observers made it probable that this was largely caused by differences of personality in observations of the Sun, and it was therefore considered better to apply no correction, but to keep the same equinox as that adopted in the 1880 Catalogue. The adopted colatitude and refractions are the same as in the 1880 Catalogue.

The Catalogues with which comparison has been made are—

(1) The Catalogue of 622 stars of the *Berliner Jahrbuch*. The places of these stars are based on Dr. Auwers' Fundamental Catalogue for the Zone Observations of the *Astronomische Gesellschaft*.

(2) The Catalogue of 303 stars given in the *Berliner Jahrbuch*, which is taken from Dr. Auwers' Fundamental Southern Catalogue for the Zone Observations of the *Astronomische Gesellschaft* between −2° and −23°. This Catalogue, with an account of the observations on which it depends (mainly those of southern observatories) is given in *Ast. Nach.*, 1890–91.

(3) The *American Ephemeris*. The positions are derived from Professor Newcomb's Fundamental Right Ascensions and Professor Boss's Declinations.

(4) Professor Newcomb's New Fundamental Catalogue, which is adopted in the *Nautical Almanac* for 1901, but is not yet published. The places have been obtained from a manuscript copy supplied by the Superintendent of the *Nautical Almanac*.

Differences in Order of Right Ascension.

R.A.	Greenwich—B.J. R.A.	Greenwich—B.J. N.P.D.	No. of Stars.	Greenwich—"303" R.A.	Greenwich—"303" N.P.D.	No. of Stars.	Greenwich—A.E. R.A.	Greenwich—A.E. N.P.D.	No. of Stars.	Greenwich—Newc. R.A.	Greenwich—Newc. N.P.D.	No. of Stars.
h h	s	″		s	″		s	″		s	″	
0 to 1	−·042	+0·21	9	−·028	+0·73	7	−·039	+0·25	9	−·071	+0·27	12
1 „ 2	−·033	−0·28	9	−·020	+0·39	7	−·050	+0·06	7	−·058	+0·19	9
2 „ 3	−·028	+0·23	10	−·018	+0·57	9	−·049	−0·02	10	−·056	+0·19	12
3 „ 4	−·024	+0·02	13	−·036	+0·54	8	−·037	−0·13	10	−·057	+0·21	13
4 „ 5	−·031	+0·04	7	−·034	+0·61	7	−·042	+0·02	6	−·050	+0·17	10
5 „ 6	−·017	−0·06	12	−·003	+0·76	13	−·032	+0·04	9	−·051	+0·21	18
6 „ 7	−·045	+0·17	10	−·040	+1·14	9	−·045	+0·03	9	−·058	+0·36	14
7 „ 8	−·033	+0·15	9	−·055	+1·06	4	−·039	−0·01	6	−·052	+0·26	11
8 „ 9	−·036	+0·36	7	−·025	+1·07	4	−·053	+0·23	6	−·063	+0·37	9
9 „ 10	−·027	+0·15	8	−·015	+0·78	6	−·029	+0·11	7	−·053	+0·29	10
10 „ 11	−·031	+0·28	11	−·037	+0·80	8	−·046	+0·11	5	−·056	+0·30	9
11 „ 12	−·024	+0·03	9	−·014	+0·62	7	−·036	+0·04	7	−·053	+0·19	9
12 „ 13	−·040	+0·23	3	−·021	+0·50	10	−·057	+0·18	7	−·056	+0·31	12
13 „ 14	−·048	+0·22	4	−·021	+0·48	9	−·035	+0·03	5	−·051	+0·27	8
14 „ 15	−·019	−0·17	8	−·025	+0·63	11	−·066	−0·13	7	−·053	+0·24	11
15 „ 16	−·019	−0·01	13	−·021	+0·25	12	−·059	−0·01	7	−·051	+0·21	14
16 „ 17	−·025	+0·34	8	−·023	+0·71	10	−·045	+0·35	5	−·051	+0·36	13
17 „ 18	−·034	−0·26	7	−·010	+0·91	13	−·040	−0·10	7	−·053	+0·26	11
18 „ 19	−·024	+0·12	11	−·030	+1·00	8	−·044	+0·15	7	−·047	+0·36	13
19 „ 20	−·010	+0·22	10	−·012	+0·81	11	−·020	+0·18	7	−·045	+0·38	16
20 „ 21	−·034	+0·11	10	−·008	+0·66	10	−·052	−0·03	7	−·058	+0·22	11
21 „ 22	−·034	−0·03	10	−·009	+0·70	7	−·020	+0·01	7	−·046	+0·33	11
22 „ 23	−·038	−0·07	12	−·021	+0·67	12	−·036	+0·19	8	−·062	+0·24	13
23 „ 0	+·012	·00	6	−·021	+0·48	9	−·052	+0·57	3	−·054	+0·30	9

Differences in Order of North Polar Distance.

N.P.D.	Greenwich—B.J. R.A.	Greenwich—B.J. N.P.D.	No. of Stars.	Greenwich—"303." R.A.	Greenwich—"303." N.P.D.	No. of Stars.	Greenwich—A.E. R.A.	Greenwich—A.E. N.P.D.	No. of Stars.	Greenwich-Newc. R.A.	Greenwich-Newc. N.P.D.	No. of Stars.
° °	s	"		s	"		s	"		s	"	
0 to 10	+·078	−·13	11	...	...	...	+·018	−0·13	4	+·289	+·02	8
10 ,, 20	−·054	−·09	43	...	...	...	−·043	−0·33	5	−·128	−·04	5
20 ,, 30	−·054	−·21	47	...	...	...	−·072	−0·04	5	−·075	+·11	10
30 ,, 40	−·032	−·13	34	...	...	...	−·036	−0·52	7	−·083	+·14	14
40 ,, 50	−·045	−·17	52	...	...	...	−·052	−0·22	12	−·062	+·11	15
50 ,, 55	−·034	+·24	27	...	...	...	−·065	−0·04	9	−·051	+·09	10
55 ,, 60	−·040	+·01	24	...	...	...	−·053	−0·10	12	−·042	+·10	13
60 ,, 65	−·037	−·17	31	...	...	...	−·062	−0·33	10	−·047	·00	19
65 ,, 70	−·023	+·11	28	...	...	...	−·045	+0·06	15	−·050	+·16	25
70 ,, 75	−·023	+·10	30	...	...	...	−·029	+0·05	9	−·058	+·11	19
75 ,, 80	−·023	+·16	28	...	...	...	−·045	+0·24	19	−·055	+·29	23
80 ,, 85	−·028	+·22	29	...	...	...	−·042	+0·07	20	−·060	+·36	30
85 ,, 90	−·010	−·02	20	−·013	+·47	23	−·034	+0·14	9	−·057	+·31	19
90 ,, 95	−·011	+·02	27	−·020	+·48	36	−·030	−0·02	12	−·057	+·30	24
95 ,, 100	−·023	+·12	23	−·018	+·70	44	−·037	+0·15	18	−·060	+·34	23
100 ,, 105	−·021	+·01	16	−·027	+·78	31	−·047	+0·02	8	−·060	+·49	14
105 ,, 110	−·034	−·01	24	−·023	+·79	44	−·048	+0·18	9	−·057	+·56	22
110 ,, 115	−·016	−·29	18	−·024	+·86	28	−·030	+0·43	6	−·056	+·50	19
115 ,, 120	+·004	−·26	13	−·012	+·94	3	−·017	+0·43	11	−·040	+·46	19

1898 *April* 6.

Observations of the companions of Sirius and Procyon, made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The cloudy weather prevented any observation of *Sirius* during the early part of the year, and it was not till Sunday, March 20, that there was a night sufficiently good for the companion to be seen. On this night the position was measured by Mr. Lewis, as follows :—

		Position Angle.	Distance.
March 20	1898·214	179°·2	4″·68

The companion was also seen by Mr. Bryant and Mr. Melotte, but they did not make any measures. The difficulty of measurement was not due to the faintness of the companion so much as to the diffused image of *Sirius* at the low altitude.

The companion of *Procyon* has been observed on three nights by Mr. Lewis.

		Position Angle.	Distance.
		°	″
March 20	1898·214	327·7	3·93
March 31	·244	326·0	4·02
April 4	·255	324·4	4·84

On two nights the companion was seen by Mr. Melotte.

The observer noted that the appearance of the companion of *Procyon* was not so like a star as that of *Sirius*, and that while the wire of the micrometer totally eclipsed the companion of *Sirius*, the companion of *Procyon* was seen on both sides of the wire.

Royal Observatory, Greenwich:
1898 *April* 4.

Observations of Nebulæ. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

In the latter part of 1897 September a series of micrometrical measures of nebulæ was begun by the writer at the Chamberlin Observatory, University Park, Colorado, U.S.A.

The working list contains all of Swift's nebulæ, and also a large number of others between the equator and 30° of south declination, the positions of which are not known to have been micrometrically measured. As the publication of this series of observations may be considerably delayed, it has been thought best to publish from time to time such preliminary results as may be of interest.

Each nebula is connected with some star in the field of view by micrometrical measures of $\Delta\alpha$ and $\Delta\delta$. The star, if not found in any good catalogue, is connected with some catalogue star by chronographic measures of $\Delta\alpha$, and micrometric of $\Delta\delta$. The last-mentioned observations are made at times when faint nebulæ are invisible because of the brightness of the Moon. The observations given below were made during the last four months of 1897 with the 20-inch Clark equatorial refractor armed with a magnifying power of 185 diameters. The mounting of the instrument was constructed by Sægmuller, and has proved to be very convenient for this work. When the positions of the nebulæ, as given in Dreyer's New General Catalogue, or in the supplementary catalogue in Vol. LI. of the *Memoirs of the R.A.S.*, are more than ten seconds in error in right ascension, or two minutes in declination, the correct positions are given. These places are, however, for 1900·0, which is the epoch of the working list.

By the liberality of Miss Catherine W. Bruce, of New York

City, a new micrometer has been built specially adapted to this work. Future observations will be made with it more swiftly and also more accurately than has been possible hitherto.

The numbers given are those of the N.G.C., except when the nebulæ are found in the supplementary catalogue above mentioned. In that case the numbers are inclosed in brackets.

24. The length of this nebula is 3′, the elongation being at 225°. A 9·5 mag. star is hard by its f extremity.

58. I cannot find this, having hunted diligently for it on two nights. Its neighbours 47 and 54 are easily seen. Probably the R.A. given for 58 is just a minute too great, and it is really identical with 47, which is a Tempel nebula.

73. Swift mentions a double star close following. Its mags. are 12, pos. angle 225°, and distance 20″.

155. The position is 0^h 29^m 37^s, $-11°$ 19′·4.

237. The position is 0^h 38^m 21^s, $-0°$ 40′·2.

283, 284, 285, 286. These are all eF, eS, with stellar nuclei of mag. 13·5. Their positions are

0^h 48^m 14^s, $-13°$ 42′·4,
0^h 48^m 25^s, $-13°$ 42′·1,
0^h 48^m 31^s, $-13°$ 42′·1,
0^h 48^m 31^s, $-13°$ 39′·3.

351. The position is 0^h 56^m 52^s, $-2°$ 28′·6.

481. The position is 1^h 16^m 13^s, $-9°$ 44′·1.

530. The position is 1^h 19^m 36^s, $-2°$ 6′·5.

589. The position is 1^h 27^m 44^s, $-12°$ 33′·4.

671. The position is 1^h 41^m 39^s, $+12°$ 37′·5.

675. The position is 1^h 43^m 53^s, $+12°$ 33′·5.

(164.) The position is 1^h 44^m 5^s, $-4°$ 24′·1.

715. The position is 1^h 48^m 20^s, $-13°$ 21′·9.

799. This has a good nuclear point of 13 mag. Its position is 1^h 57^m 6^s, $-0°$ 34′·9.

800. The position is 1^h 57^m 5^s, $-0°$ 36′·7.

809. The position is 1^h 59^m 23^s, $-9°$ 13′·0.

885. I have searched for this on three nights without success.

942–943. This I am inclined to call a very faint nebulous double star, the components being 35″ apart. The positions of the two objects considered separately are

943. 2^h 24^m 18^s, $-11°$ 16′·4.
942. 2^h 24^m 19^s, $-11°$ 16′·9.

Burnham also has examined these objects. His right ascensions agree with mine, but each of his declinations differs by nearly 1′. Probably his results were intended to be only approximate.

948. The position is 2^h 23^m 53^s, $-10°$ 57′·7.

(246.) The position is $2^h\ 35^m\ 18^s$, $+2°\ 2'.9$.
1091. The position is $2^h\ 40^m\ 43^s$, $-17°\ 57'.4$.
1092. The position is $2^h\ 40^m\ 50^s$, $-17°\ 57'.9$.
1091 and 1092 are both called vF by Leavenworth; 1092 is considerably brighter than its companion.
1639. This is described in N.G.C. as "eF, vS, R, bet. 2 st." I find no nebula, but simply an equilateral triangle of 12·5 mag. stars.
6797. This was searched for with considerable care on September 23. It was discovered by Peters, and is described as "Neb. with ✱ 9 m att f." Not even the 9 mag. star could be found. The sky was clear, though clouds came a few minutes after the search was abandoned.
6835. This is about 30″ in length, and is elongated at 80°. Two condensations are suspected in it.
6836. There is a 13 mag. star involved; other extremely faint stellar points were seen, preceding this star. The nebulosity is faint and ill-defined, most of it preceding the 13 mag. star.
6924. This seems to be a nebulous star of mag. 14, accompanied by a 13 mag., 20″ south.
6936. There is considerable confusion about the place of this object. The places obtained by Leavenworth, Professor Ormond Stone, and myself are given below, being reduced to 1900·0 :—

Leavenworth ...	$20^h\ 30^m\ 33^s$, $-25°\ 38'.0$.
Stone	$20^h\ 28^m\ 49^s$, $-25°\ 45'.3$.
Howe	$20^h\ 29^m\ 59^s$, $-25°\ 37'.5$.

As Leavenworth's declinations are usually much more accurate than his right ascensions, it seems probable that I have observed his nebula, and that Professor Stone has observed another object. I will examine the locality again next summer.
(1329.) Swift describes this as "eeF, pL, R, bet. 4 st., v diffic." I found the four stars, and within the quadrilateral formed by them I saw quite a number of minute stars, but was not sure of any nebulosity. The sky seemed free from haze.
6986. The position is $20^h\ 50^m\ 50^s$, $-18°\ 56'.9$.
6994. This cluster contains but four stars, of mags. 9–10, which form a letter Y.
7005. This is simply a coarse cluster, the three brightest stars being of mag. 9. No nebulosity is discernible.
7009. This planetary nebula is but slightly elliptical, being perhaps 15″ by 11″, the major axis having a position angle of about 70°. The colour is a beautiful greenish blue.
7010. I could find no nebula in the place given for this on

either one of two nights. But there is a nebula 10′ north of the given place, which is probably the one seen by h. However, the description "eF, pL, R, r" tallies only partially with mine, which is "eF, S, R, diffuse, with very faint nucleus."

The position is $20^h\ 59^m\ 11^s$, $-12°\ 44'\cdot1$.

7016, 7017, 7018. The positions of these extremely faint nebulæ are respectively

$21^h\ 1^m\ 25^s$, $-25°\ 52'\cdot3$,
$21^h\ 1^m\ 29^s$, $-25°\ 53'\cdot3$,
$21^h\ 1^m\ 34^s$, $-25°\ 49'\cdot8$.

7099. A cluster of marvellous beauty, the magnitudes ranging from 11 down. Its bright condensed centre is elongated at 100°. Following the main condensation, nearly 2′ from its centre, is a coarse group composed of a few 14 mag. stars. On the north side of the cluster the stars are scattered, bright, and arranged in lines. On the south side there are multitudes of stars of mag. 14.

7115. The length of the nebula was estimated to be 45″, and its breadth 10″. There is a 13 mag. star at the preceding end and a condensation at the following end; three or four other condensations were suspected lying along the axis. The position angle of the elongation was estimated as 65°.

The position is $21^h\ 37^m\ 53^s$, $-25°\ 48'\cdot6$.

7134. This was discovered by Peters, and is not a nebula; it is simply a group of three or four stars of mags. 13–14, which is about 40″ south of a 10 mag. star. A most careful scrutiny revealed no trace of nebulosity.

7136. This is a stellar object of mag. 13, which Muller suspected to be a nebula. At times it looked slightly nebulous, and at other times distinctly stellar. Nothing is visible in the place given in the N.G.C.

The position is $21^h\ 44^m\ 20^s$, $-12°\ 15'\cdot5$.

7159. Swift says "vF * sf." I find the star to be involved in the nebula.

7208. This could not be found in the position given in the N.G.C., but a nebula corresponding to the description precedes a minute. It is in line between two stars of mags. 10·5 and 11·5, 5′ apart.

The position is $22^h\ 2^m\ 41^s$, $-29°\ 32'\cdot4$.

7220. The position is $22^h\ 5^m\ 57^s$, $-23°\ 26'\cdot8$.

7246. In the N.G.C. this is given as "vl E, vgb M, * 13 n." To me the elongation seems very decided at 180°; there is a nuclear condensation of mag. 14. The star north of the nebula is of mag. 10.

7254 and 7256. These are identical. The place of 7254 is wrong in right ascension, and the place of 7256 is 10′

wrong in declination. I could find only one nebular object in this vicinity. Two of the three faint stars involved, and mentioned by Marth were seen; the third was suspected. The northernmost one was brightest, and was of mag. 14. The 11 mag. star which Muller saw 4′·5 preceding the nebula was also observed.

The position is $22^h\ 17^m\ 6^s$, $-22°\ 14'·5$.

7269. The position is $22^h\ 20^m\ 27^s$, $-13°\ 40'·5$.

7284 and 7285. The description of 7284 in the N.G.C. is "cF, cS, lE, r, D ✱ inv." The description of 7285, discovered by Lassell, is "Nebs. ✱ 1′ dist. from 7284." I judge 7285 to be simply one of the components of 7284. Both seemed to be nebulous stars. The brighter one is of mag. 12·5. The other is of mag. 13, and lies at position angle 60°, distant about 40″. Neither of the stars appeared to be double. I could not see any nebulosity uniting them, but the sky was somewhat dull. No other star bright enough to have been noted by Lassell is within 5′.

7413. The position is $22^h\ 50^m\ 4^s$, $+12°\ 41'·3$.

7425. The position is $22^h\ 52^m\ 1^s$, $-11°\ 29'·1$.

(1463.) This was discovered by Engelhardt, and is described as "neb. st. 14 m." I find in this place simply a faint double star, of distance 20″ and angle 45°. It is within a trapezoid of 10 mag. stars, the two long sides of the trapezoid being about 5′ in length.

7492. The nebulous matter is extremely faint, and besprinkled sparsely with stars of mag. 14. I can distinguish no definite form; the nebula is perhaps 2′ in diameter. It is described as being "bet. 2 D st." I find only one double which follows, and is of mags. 12 and 12·5, having a position angle of 160°, and a distance of about 40″. Though this double is thus wide and faint, there is no double as interesting preceding the nebula. There are a few scattered faint stars there.

7580. The position is $23^h\ 12^m\ 19^s$, $+13°\ 27'·6$.

7656. The position is $23^h\ 19^m\ 17^s$, $-19°\ 36'·4$.

7709. This is described as "R." I find it much elongated at 225°. It lies 8′ south of a star of 8 mag. Its length is 20″, with a possible further faint extension.

The position is $23^h\ 30^m\ 15^s$, $-17°\ 15'·4$.

7736. This follows a star of mag. 8 about 30 seconds, 3′ south. Professor Stone's description tallies with my observations except that he calls it "eF, gb M," while to me it appeared to have a bright centre equal to a 12·5 mag. star.

The position is $23^h\ 37^m\ 14^s$, $-20°\ 0'·4$.

7761. I cannot find nebulæ in the places given in N.G.C. for 7761 and 7776, but find one at $23^h\ 46^m\ 20^s$, $-13°\ 56'·2$. 7761 is supposed to precede this $2^m\ 1^s$, and 7776 to follow mine, $1^m\ 14^s$. The descriptions of 7761 and 7776 agree pretty well with each other and with mine. However, my

nebula follows a star of mag. 9 by $3'\cdot5$, while Professor Stone describes 7761 as following a 10 mag. by $8'$. Perhaps a larger telescope is required to settle the question whether 7761 and 7776 are identical with the nebula which I have found between the places assigned for them.

7803. The position is $23^h\ 56^m\ 13^s$, $+12°\ 33'\cdot3$.

7821. In the N.G.C. this is described as iF. Probably iR is meant. The nebula is about $40''$ long and $15''$ broad, the elongation being at 110°.

7828. The position is $0^h\ 1^m\ 20^s$, $-13°\ 58'\cdot3$.

7829. This follows 7828 two seconds. Leavenworth suspected it to be a nebula. I can see no nebulosity; it appears to be simply a star of mag. 13.

Second Attempt to Photograph the Leonid Meteor Swarm.
By Isaac Roberts, D.Sc., F.R.S.

The first attempt to photograph the *Leonid* Meteor Swarm was made last year, and was reported upon to the Society at the meeting held in 1897 March (*Mon. Notices*, vol. lvii. pp. 430–431).

This second attempt was made by using the ephemeris computed by Mr. Wright, of the *Nautical Almanac* office, under the directions of Dr. G. Johnstone Stoney and Dr. Downing. It included the interval between 1897 December 24 and 1898 April 8; but unfortunately the only occasions with suitable climatic conditions for taking photographs, within the range of the ephemeris, were on 1897 December 31; 1898 February 27 and March 21.

The photographs were taken simultaneously with the 20-inch reflector and the 5-inch Cooke lens, the reflector plates covering the sky area of four square degrees, and the lens an area of 230 degrees.

The December plates were exposed during 57 minutes, and the February and March plates exposed during two hours each respectively.

The sky during the exposures on each occasion was clear, and the general conditions must be considered favourable for obtaining good photographs. The stars on the plates with two hours exposures in the 20-inch reflector would be to the faintness of about 17th magnitude, and on the 5-inch lens plates about 14th to 15th magnitude.

The sum of this explanatory statement is, that after very careful examination of all the plates, three times over, no indication whatever could be perceived of the presence of the meteor swarm. We must therefore conclude that if the ephemeris is correct within the limits of the photo-fields stated above—if the meteor swarm has followed the computed orbit, in the computed

time, we must accept the photographic evidence that the meteors are very small—that they are, over the area of $2° \times 2°$, fainter than 17th magnitude, or over 230° area, fainter than 15th magnitude stars.

I am willing to try again to photograph the swarm during a period extending from December 24 this year to the end of the first week in April next year, provided an ephemeris is computed for the purpose; for I am impressed with the idea that the luminosity, and accurate position of this swarm in its orbit, ought, if possible, to be determined with the necessary accuracy, and the photographic method only can adequately furnish the data.

A Revolver Eyepiece, electrically warmed. By A. F. Lindemann.

Especially in observing double stars and planetary details I had often and rapidly to change the magnifying power of my telescope. The air would allow a power of 100; suddenly it becomes steadier for a few seconds and a power of 200 to 300, or even 420 to 600, can be used with my 6-inch glass. But before 1895 it took me 15 to 30 seconds to change it, and during this time the air often changed unfavourably, and I had to return to 100. Quite apart from having perhaps to focus the changed power a little, to light up and take my eye off the telescope, and spoiling by change of illumination the sensitiveness of the retina for the next 5 to 10 seconds, in winter—or even in a very damp and cool summer night—the new cold eyepiece, when in position, just at the most important moment, would suddenly cover with condensed moisture from the eye, and a wiping process had to be resorted to. Even when the eyepiece was previously warmed, it often cooled down during observation, and gave the same deplorable result. This induced me to construct and make an eyepiece which I have now had over three years in constant use, and which proves to be all that can be desired. The idea of a revolver eyepiece is not a new one, as at least one "vertically" revolving eyepiece exists; but my construction may have some new features, and may be of use to others as it has been to me; and the (I believe) novel idea of warming by electricity should certainly prove a boon to nearly every observer, as it can easily be applied to any telescope.

The revolver eyepiece (figs. 1, 2, 3, 4, and 5) consists of a ring (*a*) of ebonite (which I largely use with advantage), to which is screwed the ebonite carrier (*b*). The ring and carrier is slipped over the tube (A), usually carrying the eyepieces (figs. 1 and 2) up to collar (*c*). By this the position of A in relation to *a b* is fixed. The clamp screw (*e*) holds it tight in any position by pressing a small steel plate (*d*) in the usual way against A. When *e* is released *a b* can be rotated round A. Upon A is very carefully

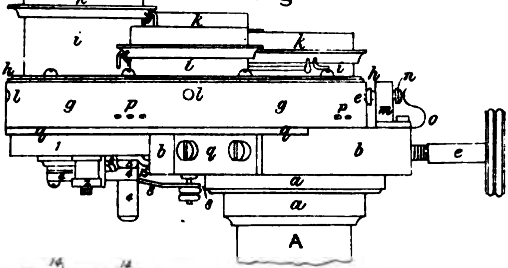


Fig. I.

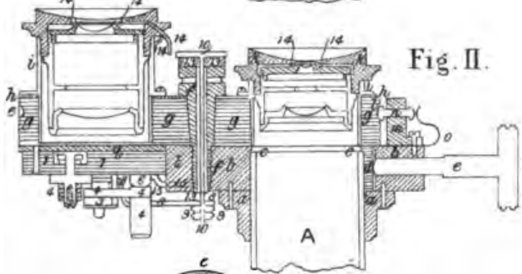


Fig. II.

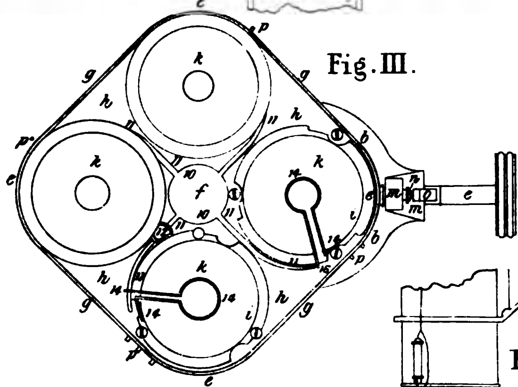


Fig. III.

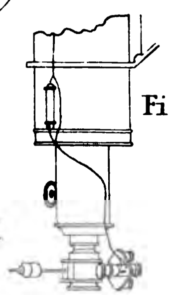


Fig. V.

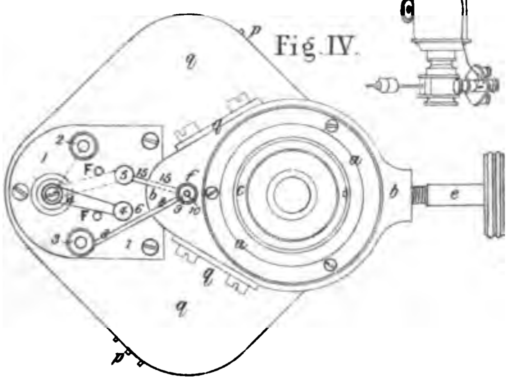


Fig. IV.

fixed the ebonite piece (g) by means of a cone and screw (f). g rotates, and is for convenience' sake made square, with rounded corners. I choose this shape so that the eye can easily be brought over the eyepiece. Even a pentagon disturbs the bringing up of the eye, as the nose and eyebrows are in the way. The piece g is in four places, and at right angles to one another, carefully pierced, so that the centres of the eyepieces to be inserted are in the same circle, central to f, and in the optical axis of the telescope. In these holes are inserted the eyepieces ($i\,i\,i\,i$) of various magnifying powers, and at such varying heights that the focus of all of them is in the same plane. The eyepieces fit smoothly in the holes and are fixed as seen in the drawings (figs. 1, 2, and 3), being held by turning them under the screw heads as shown. In turning g one power after the other is placed exactly over $a\,b$, and the power changed within half a second.

Now as to details. At m there is a slip-bolt (n), rounded off towards g, against which it presses by a spring (o). In g conical holes (l) are drilled, so that when the bolt (n) falls in one, the respective eyepiece is exactly over the centre of A; the telescope is now focussed, and the star having been set in centre of one eyepiece will be found to stand also in the centre of this or any other which may be set. The small resistance given by the bolt against turning enables the hand to feel that the eyepiece is in position. At $p\,p\,p$ are fastened near the corner, and convenient for the hand to feel, small rounded pins, which in the dark tell, by the number of them felt, what power is in hand, so that any power can be determined and easily set. An aluminium plate ($q\,q$) is fastened to b so as to protect the eyepieces from beneath against injury and dust, and is at the same time the carrier of the commutator (1).

Now as to warming. This is at present done by electricity from the primary battery, but in future will be supplied by a central storage battery. At 1 is fixed to the above-mentioned aluminium plate (q) a small commutator, 2 and 3 are the two pole clamp screws, 4 is the contact lever. The current travels along the telescope tube by covered wires to a resistance coil (fig. v.) with variable resistance, and from thence by a pliable silk-covered copper strand to 2 and 3. 2 is connected by a thick silver wire (15) to the screw foot (f). From 3 a thick hard-drawn silver wire (8) stretches to and round the thick silver wire (10), where it rests by spring action against the silver nut (9) set fast by check nut. This wire (10) passes through the ebonite plug and plate (13 . 13), inside screw and cone ($f\,f$) to the top of it, ending in plate 10, which itself stretches out in four arms (11 . 11 . 11 . 11). Fixed to $g\,g$ is the aluminium plate $h\,h$, making good contact with the head of $f\,f$, and with the tubes of the eyepieces ($i\,i\,i\,i$). By these means pole 2 is connected with all eyepiece tubes. The other pole (3) ends in the four arms (11 . 11 . 11 . 11) of thick hard-drawn silver wire, bent according to height of eyepiece as needed, and flattened at the ends, and taking the pole (3) close to the four

eyepiece tubes. The eyepiece has a head of ebonite, which screws into the eyepiece tube. This head is pierced by a thin platinoid wire (14 . 14) towards the centre, where it forms a ring and returns to the outside, where one end is bent short and flattened, making good spring contact with the tube *i* by means of a short silver strip soldered to *i*, and thereby connects pole 2. The other end of 14 stretches a little further out, and is bent sharply downwards and flattened, making good contact with the wire (11), which presses it outwards by spring action, and is therefore connected with pole 3. The eyepiece (fig. III.) on the right is to show it out of circuit, and that by turning it to the left and bending the wire 11 towards the wire 14 it will catch it and set the eyepiece for warming (see lower eyepiece in fig. III.). To insert another eyepiece, turn the one to be taken out about 10° to the right, lift it out, and fix the other by turning it the other way.

The action is the following (dotted lines show connection of commutator parts): To turn the current on, place handle 4 upon 5; current runs from 2 to 4 and 5, by 15 to screw *f* to plate *h* to four eyepieces (*i i i i*), to platinoid wires (14 . 14 . 14 . 14), from thence to arms 11 . 11 . 11 . 11 to centre (10), down to 9 and 8 and to pole 3. By this arrangement the circuit remains unbroken, although *g* is rotating. When electricity is turned on and resistance regulated, the four platinoid rings are gently warmed, and by radiation the four eyepiece lenses next to the eye are also warmed in a few minutes, so that condensation of water upon them is impossible. Before constructing this warming arrangement I considered well the effect of warming upon the eyepiece lens, but the effect is practically nil, especially as the heating is central and gentle, as it only requires a few degrees to prevent dew deposit. I have not determined the current required, as I had plenty of it, but it is of course a very simple matter for anybody to work out. It must, however, be considered that the current splits at 10 in four parts. I find the platinoid gives a very good resistance. The sliding resistance makes the regulation very simple and perfect. Perfect contacts and careful insulation of wires are of course most important; especially platinoid wires (14 . 14) must be kept well away from brass setting of lens. I have other methods for warming, but found this one the most simple and convenient, as the eyepiece can be released and exchanged in less than ten seconds. When using more than four powers it is, however, more practical to have two or three sets of four, each ready and connected to the respective wires, as the whole set can then be exchanged in less than ten seconds. I may mention that the head of the clamp screw, eyepiece tubes, commutator handle, and counter weight are painted with Balmaine's paint, also a ring round A and *a*: this helps greatly when exchanging, saves one's head, and the eye finds at once the eyepiece, no other illumination being required.

Advantages.

1. Four different powers can be used in rapid succession of half-second each, thereby making use of every fraction of time of perfect air. In this way I separated ω *Leonis* to perfection on 1895 February 28, during a fine night. But the 5 to 10 seconds of absolutely perfect vision could only be gained by this or a similar instrument, or in the ordinary way accidentally.

2. Eight to twelve powers are at disposal in sets of four each, with intervals of less than 10 seconds for each set.

3. The eyepieces are always in focus if one eyepiece is once set for colour of object.

4. The eye need not be removed from eyepiece during change of powers.

5. The revolver allows a sweep over the whole field of the object glass in any direction, a very considerable advantage, especially with higher powers. I usually set it by *e* to sweep in R.A., and then turn 90° and sweep in declination; very convenient when searching for an object of which ephemeris is not quite exact. In this way I found Brooke's Comet.

6. The very objectionable condensation is entirely obviated.

Disadvantage.—Perhaps slightly complicated, and extreme nicety in construction imperative.

I have the first eyepiece I made in use since 1895 January 16, and learned to value it more and more every starlight night. Professor Schiaparelli and Professor Max Wolf were very pleased with this instrument, especially the latter, who is himself no mean mechanic, who worked with it, and photographed it at Sidmouth in October 1896, and strongly recommended me to publish the above description of it.

Sidmouth Observatory:
March 25, 1898.

Times of Transit of the Zero Meridians of the two adopted Systems across the centre of the illuminated disc of Jupiter, 1897–98. By A. C. D. Crommelin.

In compliance with numerous requests I have computed the following list of the times of transit of the zero meridians across the centre of the illuminated disc of *Jupiter*. Those passages are given which occur next after noon on those days for which the longitude of the central meridian at noon was given in my previous ephemerides. Thus five rotations intervene between the tabulated transits, except in the case of those marked with an asterisk, which are separated from those preceding them by four rotations only. Intermediate passages can be found either by interpolation, or, with sufficient accuracy for most purposes, by applying to the nearest transit in the tables once or twice the

rotation period, which may be taken as $9^h\ 50^m{\cdot}5$, $19^h\ 41^m{\cdot}0$ for System I., and as $9^h\ 55^m{\cdot}5$, $19^h\ 51^m{\cdot}0$ for System II. :—

	System I. G.M.T.	System II. G.M.T.		System I. G.M.T.	System II. G.M.T.
	h m	h m		h m	h m
Dec. 10	5 47·8	6 3·4	Feb. 20	0 0·1*	5 26·2
12	7 0·5	7 42·0	22	1 12·2	7 4·0
14	8 13·1	9 20·6	24	2 24·4	8 42·0
16	9 25·7	1 3·3*	26	3 36·4	0 24·4*
18	0 47·8*	2 41·8	28	4 48·4	2 2·3
20	2 0·3	4 20·3	Mar. 2	6 0·5	3 40·3
22	3 12·9	5 58·8	4	7 12·5	5 18·2
24	4 25·5	7 37·1	6	8 24·6	6 56·0
26	5 38·0	9 15·6	8	9 36·5	8 34·1
28	6 50·5	0 58·3*	10	0 58·2*	0 16·3*
30	8 2·9	2 36·7	12	2 10·3	1 54·2
Jan. 1	9 15·3	4 15·0	14	3 22·3	3 32·2
3	0 37·4*	5 53·3	16	4 34·3	5 10·1
5	1 49·8	7 31·7	18	5 46·4	6 48·0
7	3 2·3	9 9·9	20	6 58·3	8 25·9
9	4 14·6	0 52·6*	22	8 10·6	0 8·2*
11	5 27·1	2 30·9	24	9 22·6	1 46·1
13	6 39·4	4 9·2	26	0 44·2*	3 24·1
15	7 51·8	5 47·3	28	1 56·2	5 2·1
17	9 3·9	7 25·6	30	3 8·3	6 40·0
19	0 26·0*	9 3·8	Apr. 1	4 20·3	8 18·0
21	1 38·2	0 46·4*	3	5 32·5	0 0·4*
23	2 50·5	2 24·5	5	6 44·6	1 38·5
25	4 2·8	4 2·6	7	7 56·8	3 16·4
27	5 15·0	5 40·8	9	9 8·9	4 54·5
29	6 27·2	7 18·8	11	0 30·8*	6 32·6
31	7 39·6	8 57·0	13	1 43·0	8 10·7
Feb. 2	8 51·7	0 39·5*	15	2 55·2	9 48·7
4	0 13·5*	2 17·6	17	4 7·5	1 31·3*
6	1 25·7	3 55·6	19	5 19·7	3 9·5
8	2 37·8	5 33·7	21	6 32·0	4 47·6
10	3 50·0	7 11·7	23	7 44·4	6 25·9
12	5 2·1	8 49·7	25	8 56·8	8 4·1
14	6 14·2	0 32·1*	27	0 18·7*	9 42·3
16	7 26·3	2 10·1	29	1 31·1	1 25·1*
18	8 38·5	3 48·1	May 1	2 43·6	3 3·4

	System I. G.M.T.	System II. G.M.T.		System I. G.M.T.	System II. G.M.T.
	h m	h m		h m	h m
May 3	3 56·0	4 41·8	June 26	7 9·5	9 23·0
5	5 8·4	6 20·1	28	8 22·5	1 6·2*
7	6 20·9	7 58·6	30	9 35·6	2 45·1
9	7 33·5	9 37·0	July 2	0 58·1*	4 24·1
11	8 46·1	1 19·6*	4	2 11·2	6 3·1
13	0 8·2*	2 58·1	6	3 24·2	7 42·1
15	1 20·8	4 36·6	8	4 37·4	9 21·2
17	2 33·4	6 15·1	10	5 50·6	1 4·4*
19	3 46·1	7 53·8	12	7 3·7	2 43·4
21	4 58·7	9 32·3	14	8 16·7	4 22·4
23	6 11·4	1 15·1*	16	9 29·9	6 1·6
25	7 24·2	2 53·8	18	0 52·6*	7 40·6
27	8 37·0	4 32·3	20	2 5·8	9 19·7
29	9 49·7	6 11·0	22	3 19·0	1 2·9*
31	1 11·9*	7 49·7	24	4 32·1	2 42·1
June 2	2 24·7	9 28·5	26	5 45·2	4 21·1
4	3 37·6	1 11·5*	28	6 58·4	6 0·3
6	4 50·5	2 50·2	30	8 11·8	7 39·4
8	6 3·4	4 28·9	Aug. 1	9 25·0	9 18·5
10	7 16·3	6 7·8	3	0 47·6*	1 1·8*
12	8 29·2	7 46·5	5	2 0·9	2 40·9
14	9 42·1	9 25·4	7	3 14·1	4 20·1
16	1 4·5*	1 8·5*	9	4 27·4	5 59·3
18	2 17·5	2 47·3	11	5 40·6	7 38·4
20	3 30·4	4 26·2	13	6 53·8	9 17·5
22	4 43·4	6 5·1	15	8 7·1	1 0·9*
24	5 56·5	7 44·0	17	9 20·4	2 40·1

7 Vanbrugh Park Road, Blackheath, S.E.:
1898 *April* 6.

Elongations of Jupiter's Fifth Satellite, 1898 *April* 10 *to June* 19. By A. C. D. Crommelin.

The period adopted in the American Ephemeris, viz. $11^h\ 57^m\ 22^s{\cdot}6865$, has been employed. This is sensibly the same as the definitive value $11^h\ 57^m\ 22^s{\cdot}6790$ deduced by Dr. Cohn from all the observations made up to 1895 January 30, the difference only amounting to about 1 minute in 10 years. Every fourth elonga-

tion is tabulated; the intermediate ones may be found by the application of 11^h 57^m or 23^h 55^m to the nearest tabulated elongation.

1898.	East Elongns. G.M.T. h m	West Elongns. G.M.T. h m		East Elongns. G.M.T. h m	West Elongns. G.M.T. h m
Apr. 10	15 23	21 22	May 16	12 11	18 10
12	15 13	21 12	18	12 0	17 59
14	15 2	21 1	20	11 50	17 49
16	14 52	20 50	22	11 39	17 38
18	14 41	20 40	24	11 29	17 28
20	14 30	20 29	26	11 19	17 17
22	14 19	20 18	28	11 8	17 7
24	14 8	20 7	30	10 58	16 57
26	13 58	19 56	June 1	10 48	16 47
28	13 47	19 46	3	10 38	16 37
30	13 36	19 35	5	10 28	16 26
May 2	13 25	19 24	7	10 17	16 16
4	13 14	19 13	9	10 8	16 7
6	13 4	19 2	11	9 58	15 56
8	12 53	18 52	13	9 48	15 47
10	12 43	18 41	15	9 38	15 37
12	12 32	18 31	17	9 29	15 28
14	12 21	18 21	19	9 19	15 18

Errata in Mr. Marth's Values of the Sun's Co-longitude, MONTHLY NOTICES vol. lvii.:—

(*Communicated by A. C. D. Crommelin.*)

Page 88, Aug. 22, *for* 218°·82 *read* 205°·82.

„ „ 23, *for* 230°·05 *read* 218°·05.

„ „ 24, *for* 242°·29 *read* 230°·29.

Page 614, Nov. 19, *for* 201°·64 *read* 210° 64.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. MAY 13, 1898. No. 7

Sir R. S. BALL, LL.D., F.R.S., President, in the Chair.

George Banaster, The Mythe Villa, Tewkesbury;
Edward I. Essam, Billingborough, Lincolnshire;
The Hon. George Stuart Forbes, I.C.S., Revenue Secretary to the Government of Madras, Madras, India; and
The Rev. William Edward Winks, 58 Richmond Road, Cardiff, South Wales,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Cecil Goodrich Julius Dolmage, M.A., LL.D., 22 Upper Merrion Street, Dublin (proposed by J. E. Gore); and

Andrew Ellicott Douglass, B.A., Lowell Observatory, Flagstaff, Arizona, U.S.A. (proposed by T. J. J. See).

Seventy-five presents were announced as having been received since the last meeting, including, amongst others :—

Harvard College Observatory Circular, No. 28 ; Photographic Spectrum of the Aurora, presented by the Observatory ; T. R. Dallmeyer, A simple guide to the choice of a photographic lens, presented by the author ; Two photographs of the total solar eclipse of 1898 January 22, taken by the Lick Observatory Expedition (lantern slides), presented by the Lick Observatory.

Vanadium in the Spectrum (C to D) of Sun-spots. By the Rev. A. L. Cortie, S.J.

In a former paper, entitled "Observations of the Spectra of Sun-spots in the region B – D" (*Memoirs R.A.S.* vol. l. p. 51), I called attention to a line near w.l. 6243·5, which was only just visible in the ordinary solar spectrum, but was very greatly widened when it crossed a spot. Since the publication of this paper my observations of the spot-spectra have been somewhat desultory, but in those which I have secured this line has been always most marked, being one of several faint lines in this region which are permanent and characteristic of the spectra of all spots. That this judgment is unbiassed is evidenced by the fact that, after a long break in the observations, when the region had become less familiar to me, and I had frequently to consult Mr. Higgs's beautiful maps while observing, the same line always claimed attention. The publication of Professor Rowland's "Preliminary Table of Solar Spectrum Wave-lengths" in the *Astrophysical Journal* has enabled me to fix the widening as almost certainly due to the very faint Vanadium line at 6243·055. The line is invisible in the ordinary spectrum with the Browning 12-prism spectroscope, but it can be seen in the second order of the grating spectroscope, and on 1891 September 7 over a spot, when it was clearly separated from the adjoining line at 6243·32, it was very much widened. Hence I conclude that the remarkable widening of the line, seen only across spots with the prism spectroscope in this position, is due to the Vanadium line. Moreover, its sympathy with the widening of other lines due to this metal is a further proof of its identity. Among such is a faint line at 6039·953 which is also much widened in all sun-spots. This has led me to study the behaviour of all the Vanadium lines catalogued in Professor Rowland's lists between C and D in the spectrum of sun-spots. The results are collected in the following table :—

No.	Rowland Wave-length.	Intensity.	Thalèn Spark.	Intensity.	Relative Mean Widening.	Remarks.
1	6039·95	0	6040·3	10	15	Always widened.
2	6081·67	0	6081·3	4	5	
3	...	...	6090·3	10	...	? 6090·43 Fe.
4	6111·87	0	6110·7	4	7	Sometimes with Ni 6111·29.
5	6119·74	1	6120·2	10	5	Sometimes with Ni 6119·97.
6	6135·58	00	6135·6	4	10	Very near Cr line 6135·99.
7	6150·36	0	...	...	9	
8	6170·42	0000	...	...	...	Not seen.
9	6199·40	0	...	...	15	Always widened.
10	6214·08	000	...	...	...	Not seen.
11	6224·72	000	...	...	...	Not seen.
12	6230·94	8	...	...	5	V and Fe.
13	6243·06	000	6241·8	6	40	Always very much widened.
14	6252·05	00	...	...	10	
15	6258·57	000	...	...	9	With Ti line 6258·32.
16	6261·50	0000	...	...	9	With Ti line 6261·32.
17	6269·08	000	...	...	30	From 4 observations only.
18	6285·38	00	...	...	...	Observed once.
19	6293·03	000	...	...	...	With O line 6293·17. Widened once.
20	6296·58	0000	...	...	...	Not seen.

The intensities of the solar lines in the third column are taken from Rowland's lists, in which a line of intensity 1 is one that is just visible on his Map of the Solar Spectrum, while intensities 0 to 0000 indicate increasing degrees of faintness. On this scale the lines C, D_2, and D_1 are of intensity 40, 30, and 20 respectively. In the fourth column are given the corrected wave-lengths of the lines of the metal observed in the spark by Thalèn, taken from Dr. Watts's "Index of Spectra," and in the next column their intensities, on a scale 1 to 10. The line 6090·3, which is one of the strongest in the spark according to Thalèn, seemingly does not appear among the solar lines. There is an iron line at 6090·43. In the fifth column is given the relative mean widening of the lines, which is an estimation of their approximate order in the spot spectrum. The want of correspondence with the normal intensities of the lines is apparent. The numbers have been obtained by taking means of all the observations of the widenings of the lines, reckoned in terms of the normal width of the lines in the ordinary spectrum and multiplying the results by 10. Thus 15 means that the line is, on an average, one and a half times as wide again in a spot as in the ordinary spectrum.

All the lines in the list are, with the one exception of a line coincident with an iron line, faint or very faint lines. Three of the faintest of all have not been observed, and five others cannot generally, with the dispersion employed, be separated from lines due to Ti, Ni, and O, which adjoin them. But the lines numbered 1, 9, and 13 are always widened in both maximum and minimum period spots. The line numbered 9 has near it two lines of the same intensity in the ordinary spectrum at positions 6194·63 and 6195·67. In observing these three lines over spots, although out of the spot they are of the same intensity, yet in the spot the Vanadium line is greatly widened, while the two others are unaffected. Such was the case, to give instances, on 1894 November 30 and December 12, and on 1896 November 6, when, at a time when the light did not allow of the lines being seen in the ordinary spectrum, the Vanadium line alone stood out where it crossed the spot, and later on, when the seeing improved, the Vanadium line was alone widened in the spot, the companion lines remaining unwidened. This is a case in which, of lines of the same intensity and near to one another, one is affected in spots and others are not, thus proving that the phenomenon observed is objective, and not merely optical and subjective. To take another example. At 6306·02 and 6306·78 are two lines of exactly the same intensity, according to Rowland and Thollon. The former of these two is both constantly and greatly widened in sun-spots, the latter never. Both these lines are due to atmospheric oxygen, yet in Thollon's map the line widened in sun-spots is, curiously enough, indicated as a solar line. Unless the widening of 6306·02 is due to some very faint solar lines on either side of its position, which with the dispersion employed would be coincident with it, the widening of this oxygen line would indicate the presence of the gas in sun-spots. Moreover, No. 19 in the list of Vanadium lines, which is a very faint line, is not two-tenths of a Xth metre removed from another oxygen line. The line at this wave-length was widened over a spot on 1896 November 8. If the oxygen line was unaffected, then the widening must be attributed to the very faint Vanadium line adjoining it. Similar remarks apply to the five lines in the above list which are close to Ti, Ni, and Cr lines. Indeed, in observations of this sort, in regions where the lines are closely packed together, unless a very high dispersion be employed, it is extremely easy to attribute the widening to lines of some particular metal, when in reality it belongs to some faint line which, with the dispersion employed, is coincident with a neighbouring line.

With regard to the presence of Vanadium in sun-spots, as indicated by the widening of these faint lines, it is noteworthy that its combining weight, 51·3, is very close to that of titanium, iron, nickel, and other elements about this atomic weight, which also are marked constituents of sun-spots. Its behaviour is very like that of the faint lines of titanium. This suggests that the

level of sun-spots is possibly the level of the faint lines of such metals as have an atomic weight about 50. To the objection that the lines of metals like calcium and sodium and the lines of hydrogen are also present, the answer seems to be that such elements are not confined to sun-spots, but extend to a great height in the solar atmosphere. Moreover, broad lines, like H and K and the C line, are generally reversed in the region about sun-spots, and the D lines frequently so. Two Vanadium lines in the region under discussion occur in Professor Young's list of chromospheric lines, but one of these is the close double due to Fe and V, which is one of the least widened of all the lines in sun-spots, No. 12 in the table, and is also the most intense of all the lines of the list in the ordinary spectrum; and the other, 6216·5, is not attributed to Vanadium in Rowland's Table. This line, however, is sometimes much widened in sun-spots; but, being of intensity 1, though a faint line, it would be one of the strongest lines of the list, if it is really a Vanadium line.

Stonyhurst College Observatory:
1898 *May* 7.

Notes on the Zodiacal Light. By William Anderson.

Mr. E. W. Maunder's note on the Zodiacal Light in the *Monthly Notices* for March has been of much interest to me, for since I first came to Madeira in the winter of 1895-96 I have given more or less attention to it, so far as delicate health and the difficulty of obtaining a clear western horizon admitted, and have arrived at conclusions somewhat different from his. Situated as I am, it has been impossible for me to examine directly either the results or conclusions of other observers, and this must be my apology if the results presented in this paper do not contain anything new. I had intended not to publish my conclusions until I had arrived at something more definite, but there are one or two points in Mr. Maunder's paper to which I wish to refer, besides which I have arrived at the conclusion that the mystery which surrounds the Zodiacal Light will never be cleared up until systematic observations are simultaneously undertaken at a number of different stations both in the northern and southern hemispheres. I have shown in the *English Mechanic* of 1896 July 17 that the variation in the appearance of the light from night to night is largely, if not entirely, due to atmospheric causes; and, as I shall endeavour to show presently, it is necessary to have simultaneous observations from several stations in both hemispheres before we can decide whether the appearances presented by the light are due to a deviation of its plane from that of the ecliptic, or solely to atmospheric absorption.

Mr. Maunder has supposed the light to consist of a disc of matter lying within the Earth's orbit, while a good way outside the Earth's orbit there exists a flat ring of matter reflecting the Sun's light. In the accompanying diagram (fig. 1) let the inner

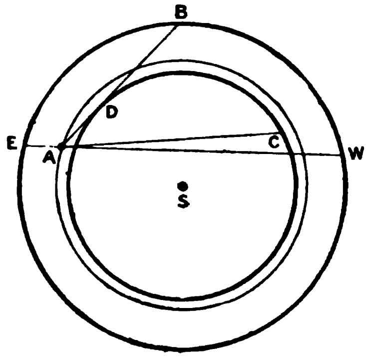


FIG. 1.

circle represent the outer edge of the inner disc of light, the middle circle representing the Earth's orbit, and the outer the "flat ring" of light, A being the Earth and E W the horizon shortly after sunset. Obviously we should see the light from the inner disc extending up from the horizon, its apex being projected on the sky in the direction A B. This disc will be brightest at its base, where, in the direction A C, we look at the particles of matter about C, which are most nearly "full," and it will fade somewhat gradually upwards, its apex at D being faint and indefinite because the particles of matter at this point will be more or less "new." Immediately above the apex of this inner light we see the outer ring at B, and from its being enormously distant at this point the ring will appear narrow and comparatively faint on account of the gibbosity of its particles. As we approach the zenith the ring will become broader, since it comes nearer to the Earth, and brighter as its particles become more "full," until at opposition to the Sun it assumes its maximum breadth and brightness. So far as I am aware, no such appearances have ever been observed, but I may be mistaken. The fact that Mr. Maunder observed the apex, not of the brightest portion of the light, but at any rate of a brighter portion of it than occurred at opposition to the Sun, at a distance of 164° from the Sun in December, and 102° in February, shows that no such break in its continuity occurred at the point B, as might have been anticipated.

In 1896 February I frequently observed the apex at a distance of 105° from the Sun; by the beginning of April it had shrunk to 70°; throughout April to 60°; on April 28, 65°; on

July 3 (a doubtful observation), 75°; and on the morning of November 14 to 85°. Throughout all this time I had often endeavoured to see the "Band" and the "Gegenschein," but never succeeded in observing either. Ill-health in the spring of 1897, and the fact of my being in Ireland during the summer, prevented observations until my return in November last. On the evening of November 13, at 7.30 P.M., I was taking a preliminary survey of the sky in order to refresh my memory in regard to the constellations and stars previous to keeping a watch for the *Leonid* meteors when what I have described in my notes as a "hazy, nebulous band" caught my eye somewhat to the east of the meridian. I had not been thinking of the Zodiacal Light at all, and this band, which I had never seen before, was fairly conspicuous. I settled its position with regard to the stars, and found on referring to the maps that it practically coincided with the ecliptic. The Zodiacal Light in the west at the time was visible as a mass of light without any definite borders or apex, so that I could not see whether the band was a continuation of the brighter light or not, *i.e.* whether the axis of the light also lay in the ecliptic, but the band passed about midway between the *Pleiades* and *Aldebaran* on the east. Since then I have seen the band on November 23, when the apex of the brighter portion of the light was 80° distant from the Sun, and on December 14, when the apex of the cone of western light was 105° from the Sun. More recently, on April 15 last, I failed to find this band; but the atmosphere seemed thick, and on the following evening (the 16th) I found the brighter western portion a shapeless mass of glowing light extending to about 60° or 65° from the Sun, and from this I clearly traced the band right across the sky, its breadth being 5° or more. The following stars lay, as nearly as I could estimate, upon its axis; but from the fact that its light was so faint that it could not be seen at all when looked at directly its axis as here indicated may easily be 3° or 4° in error.

Between κ and δ Geminorum	θ Virginis
δ Cancri	Between ι and κ Virginis
31 Leonis	„ α and β Libræ.

It therefore seems to lie entirely to the north of the ecliptic, the light of *Regulus* having evidently affected my estimate of its position in this neighbourhood. Last night (April 17) I again saw it in identically the same position. To make absolutely certain that I was not deceived—for its faintness is such that unconscious deception might readily occur—upon three different occasions between 8 and 10 o'clock I swept over it to the north and south with an opera glass, in different portions of the sky and without having first looked for it, and upon each occasion I readily located it correctly, being conscious of having run the glass across something which I could not see when looked at

directly. Now, the fact that I never saw this band in 1896, when I had often looked for it, but picked it up when nothing was further from my thoughts in 1897 November, strongly supports Mr. Maunder's conclusion that the Zodiacal Light is at present brighter than usual. But I have certainly not observed this to be the case with the cone proper, and had, indeed, decided that it was more brilliant in the spring of 1896 than now.

If we suppose the Zodiacal Light to be a flat luminous ring extending continuously from the neighbourhood of the Sun to a short distance beyond the Earth's orbit (fig. 2), then, looking

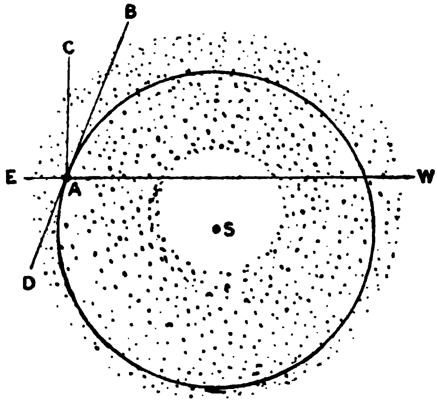


Fig. 2.

along the horizon shortly after sunset, we shall be looking through a vast number of particles of matter more than half of which, viz. those farthest away from the Earth, are almost "full," their light being diffused, and the definiteness of the edges of the further side of the ring being obliterated by the nearer, and therefore *broader*, mass of particles which turn a very small crescent of their illuminated hemispheres to us. As we view the Light further up from the horizon we at length come to a point, for example, between B and C, at which the extra quantity of more or less gibbous particles through which we look exactly counterbalances the smaller quantity of "fuller" particles on the side of C next E, and from this point we shall have a practically uniform band of light down to the horizon at E. After some hours the apex of the cone at B will sink below the horizon, which is then represented by the line B D, and we shall have nothing but the band remaining until the opposite process begins to take place on the eastern horizon before sunrise. Mr. Maunder states that "if the Light were due to a disc of matter extending uninterruptedly outwards from the Sun to a considerable distance beyond the Earth's orbit . . . the opposition portion

would tend to appear much broader than is actually the case." This, I think, would only be so if we assume a greater thickness for the disc than is necessary, or indeed probable, at its outer edges. Let fig. 3 represent a section of the outer border of the Light at right angles to the ecliptic, the Light having a thickness of, say, 10,000 or 15,000 miles where the Earth Y, is immersed in it, and tapering off towards the edge, it is quite possible that we shall only see a thickness of it sufficient to render its feeble light visible at all when we are looking toward that part of it which is included in the angle X Y Z, say a band about 5° or 10° wide, its edges being, as is actually the case, quite indefinable.

This view satisfies all the existing visible facts as to the intensity of the Zodiacal Light, so far as I am aware, except perhaps that of the Gegenschein, a phenomenon which I have often carefully sought for, but have never yet seen, although I do not see how it could have escaped me had it existed since my observations of the Light began.

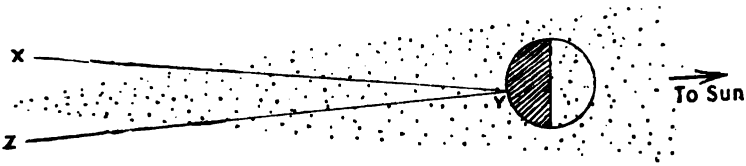


Fig. 3.

But it is quite possible that the Zodiacal Light does not everywhere extend beyond the Earth's orbit, and it is here, and when we come to deal with the plane in which it lies, that simultaneous observations in both hemispheres are necessary. As I have already shown, the Light is readily overcome by atmospheric absorption, so that when it rises from the horizon at a less angle than 90° that border of it which is nearer the horizon is liable to, and must, become more or less obliterated, throwing the axis of the visible cone to one side of its real position. Mr. Maunder says, referring to his observations of February 16–21, "The heliographic latitude of the Earth was then 7°·2 S. If, therefore, the disc extends to within a few million miles of our orbit, and if it lie in the plane of the Sun's equator, it should have shown an enormous displacement to the north of the ecliptic, which was most certainly not the case. In fact, the light appeared, if anything, to lie further south in February, when the Earth was at its maximum south heliographic latitude, than in December, when its latitude was only 3°." This last observation is exactly what we should expect if the light lie in the plane of the Sun's equator, for it is not, as Mr. Maunder appears to have assumed, those particles of matter lying between us and the Sun which give out the great portion of the visible Light, but those more or less on the further side of the Sun, as, for instance, those

near W, fig. 2. In December, however, Mr. Maunder's observations clearly show that the Light lay as nearly as possible on the ecliptic, when, if it lie in the plane of the Sun's equator, it should have been, in the evening, a long, narrow cone the apex of which lay below the ecliptic, and the axis of which was inclined to it, and crossed it at about the Sun's place. For if the plane of the Light be in the plane of the Sun's equator we should see, in the evenings, a long, narrow beam of Light in November and December the apex of which would lie to the south of the ecliptic, the Light being brightest at its centre, and fading off about equally towards both its northern and southern edges. It should then grow broader until about the beginning of March, its southern edge being brighter and better defined than its northern, because of its particles being at the further side of the Sun, and consequently being almost full, and of its increased narrowness through distance, its apex lying more or less on the ecliptic. It will again become narrow until about the end of May or beginning of June, its apex now lying to the north of the ecliptic, and its edges equally defined, and then it will grow broader until September, its northern edge now, however, being the better defined, and its apex again coinciding roughly with the ecliptic. The position of the apex, however, may vary considerably, depending largely, as it will, upon the relative densities of the outer and inner portions of the ring; and as the particles of which the Light is composed must be in constant motion, and continually taking up new relative positions, the apex may be expected to shift both in longitude and latitude within certain limits.

My observations given below, fragmentary though they be, go some way towards strengthening this view. The base of the Light most certainly becomes broader and narrower in a way which I cannot explain if the Light lie in the plane of the ecliptic.

Piazzi Smyth, in a paper published in 1852 in the Transactions of the Royal Society of Edinburgh, vol. xx. Part III., states that during the whole period of summer in the northern hemisphere, during which the Light was invisible to Cassini, it was most visible at the Cape. Cassini, he states, believed its invisibility in summer to be mainly due to the long twilight. "But these ideas (of Cassini), on being tested by the Cape observations, completely fall to the ground; for during the *whole* period of invisibility to Cassini (caused in reality by the lengthened twilight of summer in his northern hemisphere) the phenomenon was most visible at the Cape, as winter then prevails in the southern hemisphere; and, indeed, the very reverse effect from that expected by Cassini should follow when a transparent and oblate luminous ring is viewed in profile, for it will then be seen at its brightest, on account of all the infinitely small light-giving particles being brought closer together." But what Cassini contended was that the Light *should* be visible in the winter of the southern hemisphere, so that how his ideas fall to the ground

does not appear. Besides, when we see the ring edgewise, we are looking at the further and brighter portion through the entire mass of particles which are almost "new," and it therefore does not follow that the ring must be brightest when thus seen.

I believe that a series of observations carried on simultaneously at several favourably situated stations in both hemispheres could not fail to definitely settle, at any rate, the form and plane of the Zodiacal Light. Is it not of the greatest importance to ascertain the nature of matter, in which we probably live and move and have our being, which we may be actually breathing into our lungs—matter probably having a diameter of not less than 200 millions of miles, and yet incapable of obliterating the light of the faintest stars, except when it shines, which it sometimes does and sometimes does not? Telescopes and cameras have photographed stars through the Zodiacal Light and Band again and again, and yet not a trace of either appears upon the negatives, although they are visible to the unaided eye! Photography would, no doubt, yield good results in determining the axis of greatest brightness in the neighbourhood of the eastern and western horizons, but it does not seem to be capable of yielding any results with regard to the fainter extensions of the Light.

Date.	Hour.	Position of Apex.	Brightest or Best Defined Border.	Width of Base.	Distance of Apex. from Sun.	
1896.		h m °			°	
Feb. 1	7.15 P.M.	R.A. 3 40 Dec. +20		Indefinite	105	
3	7.15	3 40 +20		15° at ♈	100	
6	7.0	2 40 +15	South	30°	85	
6	8.0	4 0 +20			105	Appears conical, not lenticular.
9		1 40 +10		Indefinite	65	Faint.
March 3	7.15	3 40 +20		50°	75	Very bright.
8		3 40 +20	South		70	The faint, diffused north edge extended much farther north of the ecliptic than did the southern brighter edge south of it. Passed nearer α Arietis on N. than ζ Tauri on S. Apex indefinite.
April 3	8.45	ζ Tauri	South	30°	70	Pleiades in centre of cone.
9	8.30	ζ Tauri		Indefinite		" " "
10		Just N. of ζ Tauri		Very diffused	60	Light very diffused.
13				Faint and diffused		Very faint and diffused. Could make nothing of it.
28	8.0	δ Geminorum		Invisible in haze	65	Base appears to lie north of ecliptic.
		h m				
July 3	9.0 P.M.	R.A. 11 40 Dec. +5		8°	75	Base lies between α and γ Leonis, apex about half-way between β and ν Virginis. Extremely faint.

Date.	Hour.	Position of Apex.	Brightest or Best Defined Border.	Width of Base.	Distance of Apex from Sun.	
		h m °			°	
1896. Nov. 14	4.15 A.M.	π Leonis		10°	85	Morning observation. Spica lies much nearer S. edge of base than N.
1897. Nov. 13	7.30 P.M.			Indefinite		Traced Band right across sky, apparently nearly coincident with ecliptic. Base very indefinite.
23	7.0			Behind a cloud	80	Axis about coincident with ecliptic at δ Capricorni. From this onwards across sky Band was about 5° broad, and seemed north of ecliptic, as β Arietis touched its N. edge. It passed about midway between Pleiades and Aldebaran.
Dec. 14	7.30	ζ Tauri		About 20°	105	Base very diffused. Band right across sky, about on the ecliptic.
1898. April 15	8.0	ζ Tauri		Very indefinite	55	Pleiades in centre of base. Air seems thick. Band not seen. Light very indefinite.
16	8.30	Milky Way				Band traced right across sky, about 5° or more broad. Passed between κ and δ Geminorum, crossed δ Cancri, 31 Leonis, θ Virginis, between ι and κ Virginis, and between α and β Libræ. Band had no defined edges, and when I swept over it rapidly I thought I could trace it out to 10° broad. Western horizon glowing with diffused, indefinite light.

Funchal, Madeira:
1898 *April* 18.

The Markings on Venus. By A. E. Douglass, A.B.

(*Communicated by the Secretaries.*)

The reading public has been recently addressed on the subject of the markings on *Venus* in various attempts to show that the discoveries made at this observatory are unworthy of credit. No matter how futile such criticism must prove to be in the long run, some persons will be influenced by it if we do not from time to time make some rejoinder, or give out some statement which will show our continued activity in this line of work, our undiminished confidence in the results obtained, and our answering attitude towards adverse opinion.

In the last six years many thousands of hours have been spent by us at telescopes of 13, 18, and 24 inches aperture and their smaller finders, when the seeing was sufficiently good for profitable work on the finest known planetary detail. Expressed in standard terms, the seeing was practically always such that in a 6-inch aperture the spurious disc of the interference pattern was well defined, and a very large part of the time the rings of the same pattern were unbroken. I consider that any astronomer who cannot say the same for the seeing during his hours of work, and whose hours of work do not reach a commendable number, has no right to criticise our results; for he lacks the experience by which alone he becomes capable of judging.

Under proper conditions of air and aperture the markings on *Venus* are absolutely certain. Under proper conditions they are to me about as easy or difficult to see as the irregularities on the terminator of the Moon when it is near the first quarter, viewed by the naked eye. I have on a few occasions seen a large projection perfectly distinct. So it is with *Venus*. At the best seeing the markings are visible at the first glance.

To say that no markings save M. Antoniadi's symmetrical shadings of atmospheric contrast exist, or that the detail seen here is due to pressure on our objective, or to defective densities in the eye-piece, or to our own eyes, or to the imaginings of our brains; or, most ridiculous of all, to our looking all day at some map and then seeing it on the planet, is to offer suggestions too absurd to be taken seriously.

We use the telescope in both positions, normal and reversed: that shows that the markings are not in the lens. We use different eye-pieces and twist them in varying position angles: that shows that the markings are not there. We sit in different positions, so the markings cannot be in our eyes; and different persons in perfect independence find the same detail, so it is not a mental phenomenon.

In order to test our results in a formal manner, I made the following experiments on the afternoon of April 19, when the

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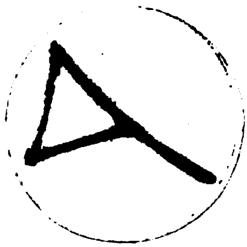

Detail seen in each combination of aperture and focus, save one, 1898 April 19

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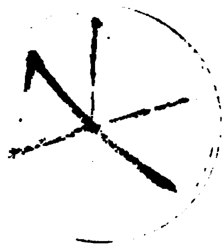

Detail drawn 1898 April 19 $10^h\ 47^m$ G. M. T

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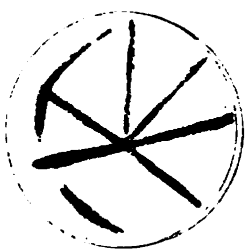


Mr. Drew's drawing of 1898 April 19, $13^h\ 5^m$

VENUS.—Lowell Observatory, Flagstaff, Arizona

seeing was very good. To improve the comparison a power of about 150 was used in every case; the detail visible and unchanged in a single essential throughout is shown in the accompanying drawing (plate 5). It is not symmetrical with respect to its centre, and therefore a reversal of it would have shown at once. In every test a complete observation was made, and in all save the first the detail was seen with absolute certainty.

Aperture. in.	Focal Length. in.	Position of Tube.	Remarks.
24	372	E. of pier	No detail; planet too bright and badly "shattered" by air currents.
3+	372	E. „	Detail perfectly evident. This aperture was obtained by a small diaphragm over the eye-piece.
3	372	E. „	Detail perfectly evident; diaphragm over objective.
3	372	E. „	Twisting eye-piece or changing position angle of eyes makes no difference.
3	372	W. „	Detail perfectly evident, and exactly the same.
1·6	372	E. „	Detail evident, not quite so well defined. Planet pure white, no diffraction ring.
4	59	E. „	Detail evident, seeing not quite so good as in 3-inch aperture.
3	59	E. „	Detail exactly the same as in long focus or better, as Sun does not shine on end of tube.
1·6	19·5	E. „	Detail the same, but not so well defined, planet yellow, diffraction ring shows.

More than twenty-four hours after making my drawings I saw Mr. Drew's drawings of the same date, and so far as mine went they coincided precisely with his in every detail. I had not seen Mr. Drew's sketches before—in fact those of April 19 were the only ones made by him since the last superior conjunction. On the other hand, I had seen Mr. Drew's drawings of last summer, when *Venus* was on the other side of the Sun, and showed entirely different markings. I had never closely studied Mr. Lowell's map—merely glanced at it casually—and at this time had not seen it in many months; and though I knew it resembled the hub and spokes of a wheel, I did not know what position the centre held with respect to the phase, and in these observations had no idea where the centre ought to be in order to give even a remote resemblance to Mr. Lowell's work.

A final bit of intrinsic evidence is the fact that I saw these lines a little broader and less well defined than Mr. Lowell represents them; that is the difference between us in our drawings of the canals of *Mars*. The difference is, I think, due to our

individual use of the telescope; for he habitually used on *Mars* a lower power, and on *Venus* a larger aperture, than I did, either one of which would tend to show the lines narrower.

When a man has had a large experience under particularly favourable circumstances, like Mr. Lowell, his report is not lightly to be set aside; and when he is almost the only one who has experienced these especially favourable conditions, an attempt by another who has never had that experience to prove his results illusions is likely in the end to bring down ridicule on its author.

The first reason why other observers have not seen these markings is bad atmosphere. When I began observing the third satellite of *Jupiter*, for days, even weeks, I drew nothing but hazy indefinite markings or belts, such things as M. Antoniadi describes as appearing to him on *Venus*. But one night after making several drawings of that character the seeing suddenly became superb, the curtain rose as it were, and I saw sharp distinct black lines about which uncertainty was impossible. The very same thing happened on the fourth satellite four days later. I had been drawing the same indefinable shadings, when one night the seeing improved, the curtain again rose, and I perceived sharp definite lines. After once thoroughly understanding the character of the object sought, I could see them and profitably study them under conditions of seeing formerly prohibitory.

The experience on *Venus* has been similar. On the day succeeding my first good view, I spent nearly the whole afternoon without catching a single certain glimpse. Suddenly the seeing improved for an instant, and I saw the same markings unmistakably. If it had not been for that glimpse I would have gone away perfectly ready to believe that no markings existed. I am not surprised that other astronomers doubt them.

The second reason why some other observers have not seen them has been the fault of using too large an aperture. Six years ago I discovered "air waves," and over four years ago I explained theoretically why reducing the aperture is often beneficial. All this has been published in full elsewhere (*Am. Met. Jour.* 1895 and *Pop. Ast.* 1897). I decided long since that in planetary work the greatest efficiency is obtained with the smallest aperture which supplies the required illumination. There is a limit to this, however. An inch and a half lens shows the markings on *Venus* nicely, but they are not so well defined as in a lens of three inches, which in our atmosphere is a very satisfactory size to use. When the seeing is very bad an aperture of less than three inches will become necessary.

A third cause of failure is the effect of heating of the lens and tube by the Sun's rays. For this reason I have found it sometimes advantageous to use the small finder, which is far within the dome and well shaded.

A fourth cause comes from the air within the dome being colder than that without. This is likely to harm the seeing. If

the interior is warmer than the exterior, it will certainly harm the seeing. In fact my latest experiments show that any dome at all is harmful. A sunshade surrounding the tube would be better both night and day.

A fifth cause of failure, and by no means the least important, is the lack of continuity of observations and the lack of a first good view. By the first I mean fair or good observations made many days in succession. For instance if the seeing is only fair it requires the work of several nights in succession, without intervals, to identify with certainty the longitude presented by a satellite of *Jupiter*. By a "first good view" I mean the necessity of one first-class observation before one understands what is sought. After that view the observer can obtain valuable results under conditions in which formerly he failed completely from ignorance of what he was after. It is the same in observing the *Gegenschein*. I have taught many persons to observe it, and I find that teaching consists in getting them to see it well once. After that they can be trusted to pick it out with very small liability to error. This, of course, is most true in atmospheres unclouded by smoke and unlighted by electricity.

No matter how difficult to obtain, a just hearing is our right. No one is entitled to cry out against us until he can show that his atmosphere is approximately as good as the one through which Mr. Lowell discovered these markings. Let our dubious friends, who attempt to show that we as well as they are deluded, devote a portion of their valuable time to work at the telescope under better atmospheric conditions, and no one will misunderstand the silence which will follow.

Lowell Observatory, Flagstaff, Arizona:
1898 *April* 26.

Micrometrical Measures of the Double Stars β 883, Sirius and Procyon. By T. J. J. See, A.M., Ph.D. (Berlin).

During the past season we have kept watch on the movements of β 883, and have taken occasion to measure the systems of *Sirius* and *Procyon*, which require very steady definition and of course a powerful telescope. When we first examined β 883 in 1897 August it was evident that no great change had taken place since our last measures in Mexico, and our subsequent observations confirm the slow motion of the companion during the past year. We have just measured these systems, and as they will soon disappear in the west, I submit at this time the results at which we have arrived. Each measure is the mean of three settings of the micrometer.

β 883.

t	θ_0	ρ_0	Remarks.
1897·622	38·6	0·25″	Closer than at Mexico.
1897·832	36·1	0·36	Clearly divided with black line between components; power 1,500, and great care for angle in last measure.
·832	37·5	0·34	
·832	39·4	0·33	
1898·263	42·3	0·29	Excellent conditions.
·263	42·3	0·23	
·263	45·4	0·27	
·263	43·2	0·27	
1897·622	37·9	0·28	Cogshall.
1897·832	45·7	0·31	Boothroyd.
1898·263	42·9	0·31	,,

These measures show that the angle has not changed more than 6° or 8° during the past year, and it appears that the distance is nearly constant. As the system from 1894 to 1895 moved over an arc of something like 25°, the present result would indicate a longer radius vector, which is also apparent in the measures of distance; the provisional orbit published in *Monthly Notices*, 1897 May is thus in accord with these observations; but at least another year must pass before we can form a trustworthy conclusion as to the character of the orbit. These results, however, distinctly indicate great elongation of the apparent orbit in the parts of the first quadrant now being described. The star separates with a power of only 500 on the 24-inch refractor, and is thus easily measured. In about another year I suspect that the distance will be greatly diminished, and then the angular motion will become very rapid.

Sirius = *A. G. C.* 1.

Besides the measures published in *Astronomical Journal*, No. 418, the following have just been secured :—

t	θ_0	ρ_0	Remarks.
1898·263	169·6	4·84″	Companion fairly distinct, but a little obscured by the rays of the large star.
·263	167·2	4·43	
·263	169·1	4·50	
·263	168·6	5·02	
1898·269	170·1	5·06	
·269	167·2	4·84	
1898·296	169·6	4·71	
·296	170·0	4·76	
1898·273	168·9	4·79	
1898·263	169·1	4·36	Boothroyd.
·269	170·9	4·97	,,
·296	172·2	5·26	,,
1898·273	170·7	4·86	

The motion appears to accord almost perfectly with the orbit given in the *Researches on the Evolution of the Stellar Systems*, vol. i. p. 84, and it is hardly likely that the companion will ever deviate materially from the path there given.

Procyon = Bessel-Schaeberle 1.

t	θ_0	ρ_0	Remarks.
1897·829	329·4	4″·80	About as difficult as companion of Sirius.
1898·263	326·6	4·36	
·263	326·0	4·41	
1898·296	324·6	4·68	Beautifully separated for some moments, companion distinctly purple.
·296	327·3	4·62	
1898·189	326·6	4·57	
1897·829	328·6	4·82	Boothroyd.
1898·263	324·0	4·48	"
1898·296	328·5	5·04	"
1898·129	327·0	4·78	

The first of these measures was made in the autumn just before we issued the catalogue of new stars, and is therefore appended to the measures of known stars communicated to the *Astronomische Nachrichten*.

The measures on the last night (April 19) were extremely satisfactory, and unquestionably indicate orbital motion since Schaeberle's discovery a year and a half ago. As the companion is distinctly purple, the appearance of the system would indicate physical connection. There can no longer be any doubt, I think, that this is the perturbing body suspected by Bessel from irregularities in the proper motion of the bright star. A refined investigation of all the meridian observations of the past fifty years, or a revision and extension of the work of Auwers in connection with recent micrometer measures, would be highly interesting. The present results, combined with Professor Schaeberle's early measures, indicate an annual motion of nearly 6°. This object, like the companion of η *Centauri* $=\lambda_1$ 207, is easy when the seeing is very steady, but at other times is hopelessly lost in the rays of the large star. The companion is of about 13th magnitude, and would offer no particular difficulty save for its closeness to *Procyon*.

Lowell Observatory, Flagstaff, Arizona:
1898 *April* 22.

The Relative Motion of the Components of γ Leonis. By S. W. Burnham.

As a double star this is one of the most brilliant objects in the heavens, and, as it is within the reach of the smallest telescopes, it has received the attention of all the leading observers

in the last hundred years. It was discovered, or first recorded as a double star, by Herschel I. in 1782, who observed it long enough to recognise the change in the direction of the smaller star. In 1824 Herschel II. said, "There can be no doubt of the motion of γ *Leonis*, though it is probably less rapid than supposed by Sir W. Herschel." From that time it was generally regarded as a binary system, although the relative change was very slow, and the character of it necessarily doubtful. The entire angular motion between 1782 and 1895 is only about 30°, and since the first reliable measures of distance the change to this time is only 12°.

Notwithstanding these unfavourable conditions, attempts have been made to show not only that this is a binary, but to determine the period, and other elements of the orbit. From the measures down to 1845 Hind computed an orbit by the graphical method of Herschel, and found a period of 296 years (*Monthly Notices*, vol. vii. p. 96). As to the value of any such investigation it is only necessary to say that between 1845 and 1830, the date of the first measures which could be of any material use in such an investigation, the companion star had moved less than 5°. Of course the angles of Herschel would be useful if supplemented by complete measures covering an arc of sufficient length to clearly define the apparent path of the companion, but the character of the movement, to say nothing of the exact details of the supposed orbit, could not have been more absolutely unknown in 1845 if the star had never been measured at all.

Since that time another orbit has been computed by Doberck, using the measures down to 1875 (*Trans. R.I. Acad.* vol. xxv.; *Monthly Notices*, vol. xxxv. p. 397; *A.N.* 3448). He found a period of 402·62 years. Between this date and the first measures of Struve the angular motion was less than 10°. Obviously the problem was as indeterminate as ever so far as any particular form of orbit was concerned, even if it were conceded that it was a binary system.

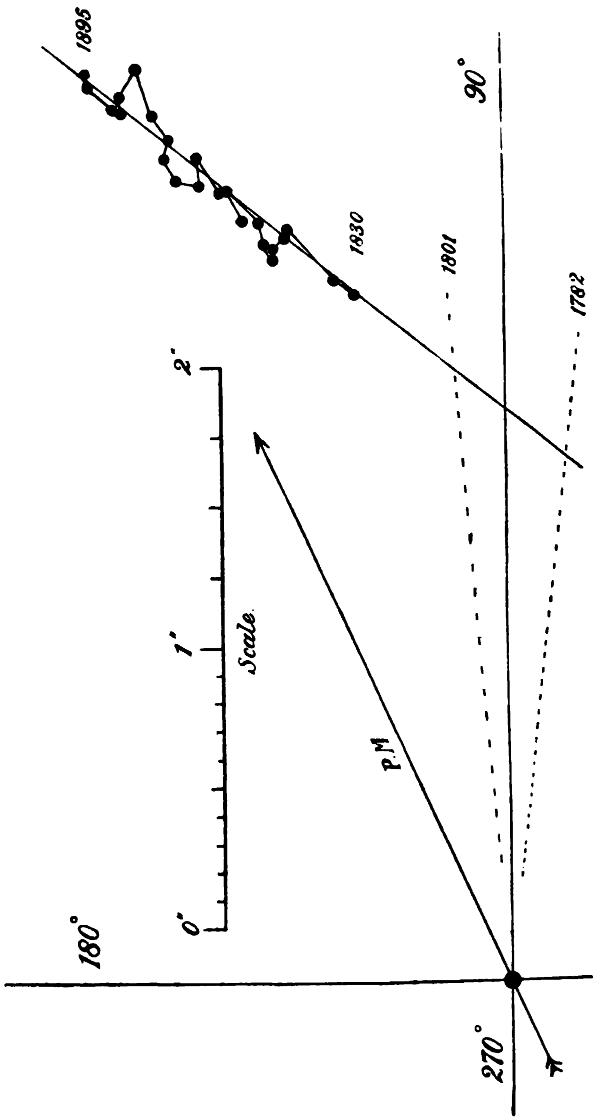
Some time since I laid down to scale some of the principal measures in the last sixty years, and called attention to what seemed to be an obvious fact that the components of γ *Leonis* were probably moving in space with nearly the same proper motion, and in nearly the same direction, like the components of 61 *Cygni* and many other pairs of that type, and showing that at all events the relative change established by the measures was perfectly accounted for by the theory of rectilinear motion. The interest of the subject, especially in view of the fact that the binary character of this pair is still insisted upon, may warrant a more thorough and complete investigation of the observations upon which the orbits referred to have been based, and the measures more recently made; and I have therefore brought together the observations of the best observers during the entire period. They are given in the following table:—

Measures of γ Leonis.

	°	"	
1782·71	83·5	...	H 2
1801·72	94·8	...	H 7
1830·38	102·4	2·52	Bes 9; Σ 11; Da 8
1833·35	103·7	2·59	Σ 10; Da 11
1840·70	106·1	2·81	OΣ 11; Ma 7; Da 5
1843·09	106·5	2·78	Da 4; Ma 14
1846·56	107·5	2·76	OΣ 12; Ma 5
1847·87	107·8	2·72	Ma 17; Da 7
1851·07	108·1	2·78	OΣ 6; Ma 16; Da 2
1853·40	108·0	2·86	Ma 46; Wr 2; Da 3
1855·30	109·3	3·01	Wn 3; Δ 16; Se 4; Wr 3
1857·51	109·0	2·89	Ma 29; OΣ 5
1860·71	109·8	3·01	Ma 9; Wr 2; Da 7; OΣ 5; Δ 12
1865·31	110·5	3·16	En 17; Se 3; Da 2; Kn 3
1868·33	111·0	3·06	Δ 9; Du 11; OΣ 3
1871·61	112·3	3·11	Δ 12; Du 20; OΣ 3; Kn 3
1875·05	112·5	3·20	Sp 12; Du 9; OΣ 2
1877·05	111·7	3·26	Δ 9; Sp 7
1878·92	112·1	3·36	Hl 10; Sp 9; OΣ 3
1880·83	112·0	3·54	Franz 4; Big 5; Sp 5
1882·88	113·5	3·47	Sp 15; Küstner 7; En 5
1884·86	113·8	3·42	Sp 18; Hl 7; En 6; Per 5; T 3
1888·56	114·2	3·44	Sp 22; B 3; Maw 3; OΣ 2
1892·32	115·0	3·55	Big 10; Lewis 4; Com 6; Lv and J 6; Glase 2; Ho 3
1895·44	114·8	3·60	Com 9; Collins 3; Scott 5; Lewis 3; Glase 2

These positions represent altogether measures on 621 nights, and each angle and distance given is, on the average, derived from measures on 27 nights. Certainly nothing in the way of micrometrical measures could be expected to give any more reliable results when the observers and the number of measures are considered. It will be remembered that this is one of the easiest stars to measure in the heavens, and no more accordant results can be looked for with present instruments and methods of observing.

These measures, and the two angles of Herschel in 1782 and 1801, are shown to scale on the accompanying diagram. It is obvious from inspection that the relative movement of the companion is sensibly rectilinear, and that all the measures are represented with substantial accuracy by the theory of rectilinear



γ Leonis.

motion. This is shown by the diagram better than it could be by any tabulated results. The annual apparent motion of the companion, derived from all the measures between 1830 and 1895, is found to be 0″·0192 in the direction of 141°·7. The corrections to be applied to the measures are shown in the following table :—

	°	″	
1782·71	+1·5	(1·94)	2n
1801·72	−0·8	(2·16)	7n
1830·38	+0·7	+0·05	28n
1833·35	+0·2	+0·02	21n
1840·70	−0·4	−0·09	23n
1842·09	−0·2	−0·02	18n
1846·56	−0·4	+0·06	17n
1847·87	−0·5	+0·12	24n
1851·07	−0·1	+0·11	24n
1853·40	+0·5	+0·07	51n
1855·30	−0·4	−0·04	26n
1857·51	+0·3	+0·10	34n
1860·71	+0·2	+0·03	35n
1865·31	+0·3	−0·04	25n
1868·33	+0·3	+0·11	23n
1871·61	−0·4	+0·11	38n
1875·05	0·0	+0·08	23n
1877·05	+1·1	+0·06	16n
1878·92	+1·0	−0·01	22n
1880·83	+1·4	−0·16	14n
1882·88	+0·2	−0·05	28n
1884·86	+0·2	+0·03	39n
1883·56	+0·3	+0·08	30n
1892·32	+0·1	−0·01	31n
1895·44	+0·7	+0·03	22n

It is hardly necessary to say that these computed deviations are less in both angle and distance than the probable errors in the results obtained by the best observers with the best modern instrumental appliances ; that is, no observer could expect any closer agreement by a repetition of his measures.

Upon this theory of motion the following ephemeris is based :

	°	″
1898·5	115·9	3·68
1902·5	116·4	3·75
1906·5	116·9	3·82
1910·5	117·4	3·98
1914·5	117·8	3·96

The principal star of γ *Leonis* has a well-determined proper motion. The meridian observations are ample for the purpose, and there is every reason to believe that the movement so found is as accurate as the recognised proper motion of any other prominent star. From this motion the real movement of the companion star is readily deduced. Taking Auwers' value for the motion of the brighter star, we have for the proper motions of the two stars

A = 0″·323 in the direction of 114°·9
B = 0·340 „ „ 116·4

The ninth magnitude star W^1 x. 234, about 4′ distant in the direction of 290°, has a still larger proper motion, but in nearly the opposite direction. Porter gives this movement from meridian observations as 0″·495 in 270°·9. The micrometrical measures of this star from γ *Leonis* by OΣ give substantially the same value.

Yerkes Observatory:
April 26.

Photographs of the Nebulæ in the Pleiades, of Stars in the Surrounding Regions and of Spurious Nebulosity. By Isaac Roberts, D.Sc., F.R.S.

The photographs annexed are prints from the original negatives, which were taken with the 20-inch reflector and the Cooke 5-inch lens respectively, the exposures of the plates being simultaneous during ten hours. 1st, on 1897 December 22, during $3^h\ 20^m$; 2nd, on the 23rd, during $3^h\ 0^m$; 3rd, on the 25th, during $3^h\ 40^m$—three exposures during an interval of four days. The sky on each occasion was very clear.

Scale of the reflector photograph, 1 millimetre to 81·45 secs. of arc.

Scale of the lens photograph, 1 millimetre to 415 secs. of arc.

On examination of the reflector photo-negative, it is seen that the *Merope* nebula extends from that star to the distance of about 40 minutes of arc, and faintly covers an area of about the same width, in the *south*, *south preceding*, and *south following* directions; the *Maia* nebulosity also extends about 40 minutes of arc in the *nf* direction. The other stars and the nebulosities, which together form the group of the *Pleiades*, and were depicted on my photograph of 1888 December 8, are shown with but little further extensions or obvious changes of form during the nine years' interval, though the density is greater on the present one owing to the longer exposure.

The photograph taken with the 5-inch lens covers an area of the sky measuring about 17° by 17°, of which a little over 10° by 10° are shown annexed, with *Alcyone* in the centre, and it will be observed that the group of the *Pleiades* is completely obscured by the photographic effects of atmospheric glare, to which reference will be made further on. All the stars brighter than the 11th magnitude are, on the negative, visible through the glare; but the fainter stars, together with the known real nebulosities, are entirely obliterated because their light is feebler than that of the glare itself.

Other photographs of this group and of the surrounding regions were also taken with the 20-inch reflector, and simultane-

PHOTOGRAPH OF THE PLEIADES

20 in. Reflector—Exposure 10 h.

1

2

PHOTOGRAPH OF THE PLEIADES

5 in. Lens—Exposure 10 h.

ously with the 5-inch lens, on 1897 October 28, with an exposure of the plate during eight hours, and on 1897 November 19 to 22, with aggregate exposures of the plate during $9^h\ 2^m$. Besides these, several photographs with exposures of the plates during intervals varying between one minute and four hours respectively have been taken during the past ten years.

The descriptive matter following relates to the reflector-photograph annexed hereto, and shown on the screen, as well as to the other two with long exposures, referred to above.

The nebula round *Merope* is of a streaky character, with the star in the centre of the denser part: the streaks trend in *south following* to *north preceding* directions for a distance of about 16 minutes of arc, and then curve in the direction *south preceding*, where the nebulosity becomes very faint but still streaky in character, and spreads out to the extent of 50 minutes of arc in breadth. It does not seem to commingle in any degree with the other adjacent nebulosities, and there are four faint stars involved in it within a distance of 60 seconds of arc from *Merope*. Besides these, there are other bright and faint stars involved in the nebulosity.

A straight streak of dense nebulosity extends across the two stars 1 and 7 (*Bessel*): it is about 19 minutes of arc in length, and does not seem to form a part of any of the other nebulosities. I infer that it is an independent nebula seen edgewise, and there is a bright star at its centre and three faint stars apparently involved.

Electra does not seem to be involved in nebulosity, but there is a streak of strong nebulosity extending to a distance of about 14 minutes of arc from it towards the *following* direction, and it is divided along its full length into two equal parts by a faint dark streak. Six stars of between 13th and 16th magnitudes are apparently involved in this nebula, which is seen edgewise, and is, I think, independent of the others. The nebulosity which extends from *Maia* crosses the streak above referred to at an angle of 45°, but no physical result seems to have been caused by this, which confirms the idea of the separate existence of both nebulæ.

Alcyone is surrounded by nebulosity of both a streaky and flocculent character. The streaks on the *following* side trend *south following* to *north preceding*, and those on the *preceding* side cross the streaks of the *Maia* nebula at nearly right angles, without appearance of either disturbance or of commingling. This again points to the nebulæ being independent. To the north of *Alcyone* is a streak of nebulosity 30 minutes of arc in length, slightly curved towards the north, and involves the stars 10 and 24 (*Bessel*), besides twelve other stars of between 12th and 18th magnitudes. This appears to be an independent nebula seen edgewise, and is probably of a spiral character. The north part of the *Alcyone* nebula seems to cross this streak without causing any disturbance to either of them.

Maia is surrounded by streaky nebulosity trending north and south in parts, and *north following* to *south preceding* in other parts. To the *north following* it extends in a long streaky arm a little beyond the star 12 (*Bessel*)—a distance of about 44 minutes of arc, and on the *north preceding* side reaches *Taygeta*. There is also evidence of very faint nebulosity extending 30 minutes of arc on the *south following* side towards *Maia*.

No clear proof is given that *Pleione* and *Atlas* are involved in nebulosity.

It appears to me that the evidence, taken as a whole, points strongly to the probability that the *Pleiades* consist of a group of stars seen by us either behind or else in front of a group of nebulæ, *Alcyone*, *Merope*, and *Maia* being involved in nebulosity; but at present there is no indication of physical connection between the other nebulæ and these three, or with each other. I may further add that it will be an exceedingly difficult work to extend materially the knowledge we now possess concerning the group until movements, and changes of structure, can be detected amongst its components.

I shall here draw attention to a paper by Professor Barnard, published in the *Monthly Notices* of this society, vol. lvii. pp. 10–16. On p. 14 he states: "At a meeting of the B.A.A. on April 29 Dr. Roberts took a further opportunity to object to these star pictures, and is reported to have said the exterior nebulosities shown on my *Pleiades* photographs were not nebulosity, and he made the assertion without fear of anyone proving the contrary. . . . That these nebulosities exist as shown on my photographs there can be no doubt whatever."

A copy of the photograph referred to and also a diagram-sketch are appended to his paper; and his photo-copy of the original negative is placed in the archives of the Society, and will now be shown on the screen. Those who will take the trouble to examine these photographs will be struck with the very coarse character of the film; with the distorted images of the stars; with the halation circles round the brighter stars, caused by the omission of backing the plate; and with the large patch of something (stated to be nebulosity) covering the group of the *Pleiades*; and it is upon this one defective photograph that Professor Barnard bases his unqualified assertion that there is no doubt whatever that these nebulosities exist as shown on his photograph. The vague suggestion of visibility in a telescope is quite inadmissible so long as the bright nebulosities known to exist in the group cannot be seen.

The six photographs (three with the reflector and three with the 5-inch lens) which have been taken at my observatory between 1897 October 28 and December 1—a copy of the latter being hereto annexed—entirely discredit the existence of Professor Barnard's nebulosity. These photographs were taken with proper care; the star images are not distorted; there is no halation effect; the sky was clear during the various exposures of the

plates, and the exposures were equal as regards photographic effect, for the stars and nebulosities shown on the plate with 10 hours are also shown on the $9^h\ 2^m$ and on that with 8 hours' exposure.

I must further remark on Professor Barnard's paper that in it he misquotes from my work—misconstrues my statements—gives measurements of the distances of certain nebulæ, on two of his photographs, which are in error to the extent of so much as 2½ degrees in 8 degrees on one, and 53 minutes in 4 degrees on the other; counts stars on a plate I have never seen, and of which I know nothing, then by this insinuates that my count of the stars on another plate, which he sent to this Society, cannot be correct; states that I have distinctly denied the existence of nebulosity in certain parts of the sky, whereas the reverse of this is true—for I have shown and published not only the existence but also the structural details of the nebulosity. This list does not exhaust the statements contained in the paper that require correction.

When very sensitive gelatine plates have been exposed to the sky during several hours they are liable to show, after development, dark patches of unequal density on various parts of the films, the light and dark parts presenting the appearance of nebulosity. These appearances may be caused by imperfections in the lenses used; by coarseness of grain and irregularities in the films; by insufficient cleaning or of smears on the plates; by slowly passing clouds during the exposures, or by omission of simultaneously flooding the films in developing the plates. The appearances may also be intensified by moonlight, or by omitting to back the plates, with a non-reflecting material, to prevent the effects of reflections of starlight (halation) from the back of the negatives. In making positive, or contact, copies of such negatives the film defects referred to are greatly intensified, and during the correlative operations the appearances of spurious nebulosity are also intensified.

Besides these mechanical defects there is the physical cause, due to illumination by starlight of the Earth's atmosphere, which affects the sensitive films during long exposures of the plates. This produces those appearances of spurious nebulosity in which the stars in the Milky Way seem to be immersed, and is one of the chief causes that mislead the inexperienced in stellar photography.

The scale of the photographs taken with portrait lenses of 6 inches aperture and under being small, and the photo-images of the bright stars relatively large, the stars down to the 4th or 5th magnitude to which the photo-plates have been exposed during intervals of from 4 to 10 hours have their photo-images involved in circles of apparent dense nebulosity—and all forms of instruments show these effects—which in reality are due to the atmospheric illumination by the light of the stars and to

diffraction. A similar effect is often visible to sight round the Sun, Moon, and bright stars.

The bright stars which form the group of the *Pleiades* when photographed on the small scale of portrait-lens pictures with exposures of the plates during eight or ten hours will, after development, appear as black spots in the midst of atmospheric glare, and not a trace of the real nebulosities, known to exist in the group, can be detected upon them. Thus also in the case of those vast areas of bright and faint stars in the Milky Way, and in other crowded star areas, when they are photographed on the small scale of portrait-lenses, have their aggregate light, which illuminates the Earth's atmosphere over the area photographed, concentrated by the lens upon the photo-film, and thus producing the appearance of the stars being immersed in nebulosity. The contiguous areas in the sky, that are in the field of the lens and have few stars upon them, add to the illusion of nebulosity by causing structural features in the atmospheric glare.

The diffused starlight of the sky, even on dark clear nights, has a powerful effect upon very sensitive photo-films, and I have made several experiments in order to enable me to judge its relative intensity during long exposures of the plates simultaneously in the reflector, in the 5-inch lens camera, and inside a blackened box 6 inches square by 12 inches in height with the open end pointed to the zenith. Parts of the plates in the box were exposed to the sky uncovered, whilst other parts were covered with black paper or with rectangular pieces of polished plate-glass of various thicknesses between 5·63 and 45 millimetres. Exposures were also made under sensitometer scales. By combinations of these methods I have been enabled to estimate the photographic effects of the atmospheric glare upon sensitive films exposed simultaneously in the 20-inch reflector, the 5-inch lens, and to the open sky, under precisely similar conditions as to quality of the sky, duration of exposure, equality in the sensitiveness of the plates, and similarity in the development.

The results showed that the uncovered parts of the films placed in the box were darkened by the sky glare to about the density of the photo-images of stars of the 16th magnitude as they appear after exposures of two and a half hours in the 20-inch reflector, whilst the parts covered with black paper were unaffected, and after development the films were as clear as the glass plates. The parts of the films that were covered with plate-glass had gradations in the photo-density proportional to the absorption and reflection from the surfaces of the light by the respective thicknesses of the plates of glass.

The bearings of these results upon stellar photographs by assisting in the production of appearances of spurious nebulosity are obvious; and it is to the causes referred to in the foregoing paragraphs that the erroneous ideas of the existence of enormous fields of nebulosity in and about the Milky Way have been generated.

Where real nebulosity exists it is confined to areas relatively small, seldom exceeding two or three degrees in extent.

The evidence now laid before us may be applied to the interpretation of the large areas of so-called nebulosity shown on many photographs that have been presented to the Society or published in *Knowledge* and in other serials.

Referring again to the six photographs of the *Pleiades* that were taken with the reflector and the 5-inch lens, with exposures respectively of 8^h, $9^h\ 2^m$, and 10^h, it is found that upon those taken with the 5-inch lens the faint stars which are shown on Professor Barnard's photograph with $10\frac{1}{4}$ hours' exposure are also shown, but no trace whatever is there of what he designates as the distant nebulosity. But on the photographs taken simultaneously with them by the 20-inch reflector there is much spurious nebulosity visible; and that it is spurious, and not real, is proved by the fact that, though it appears on each of the three photographs, it does not coincide, either in density, or in position, or in extent, on any of the plates. This could not happen if it were due to real nebulosity, or to concentrated starlight, or even to defects in the lenses; it must be due to chemical and to atmospheric causes, for otherwise the photo-effects would be alike on each of the plates.

The spurious nebulosity is shown in cloud-like patches, and simulates the real nebulosity so closely that its true character could not be decided, with certainty, without the careful correlation of two or more photographs taken at different times of the same areas in the sky.

A Determination of the Proper Motions of the Greenwich Clock Stars from the Greenwich Transit Circle Observations, 1854–1896. By W. G. Thackeray.

The old Greenwich observations of right ascension are, as is well known, affected by systematic errors due to imperfect clock-star places. To get rid of these errors the places of the clock stars for the last twenty-five years have been specially corrected to the results of the 12-hour groups, with what marked success the 1880 and 1890 catalogues have fully demonstrated. To eliminate these errors in a perfectly orthodox method requires a large amount of honest labour, while the application of arbitrary corrections is not altogether satisfactory. As the Greenwich Transit Circle has been in constant use for nearly half a century, and a considerable number of observations of the clock stars have been made with it during this period on a uniform system, it seemed well worth while to discuss the series of observations with a view to compare the results thus obtained with those derived from much longer and varied series by Professors Auwers and Newcomb.

The right ascensions and north polar distances used in this discussion are those given in the Greenwich 1860, 1864, 1872, 1880 Catalogues, and the results of the ten years' observations 1887–1896 (those not yet published by permission of the Astronomer Royal), modified as fully explained below and reduced to 1890 by the use of the Struve-Peters value of precession, and the proper motions determined by Professor Auwers from Bradley's observations. This system of reduction is generally referred to in this paper as "Auwers'" or "A"; while "Newcomb's" or "N" refers to Professor Newcomb's latest determination of the precession, and proper motions used in his fundamental catalogue for 1900.

Right Ascensions.—The correction for equinox is that determined by a former paper (*Monthly Notices*, vol. lvi. 9) from a discussion of the observations of the Sun made at Greenwich during the years 1836–1895. The actual value of the correction is the difference between the quantity applied in each catalogue and that derived from the formula

$$+0^{s}\cdot015 + 0^{s}\cdot132\ T,$$

where T is the fraction of a century from the adopted epoch 1880.

The following are the values of these corrections actually adopted :—

1860	$-0^{s}\cdot004$	1880	$+0^{s}\cdot015$
1864	$+0\cdot008$	1887–1896	$+0\cdot028$
1872	$+0\cdot009$		

The adopted right ascensions for the years 1887–1896 are the standard right ascensions adopted in the clock-star list for 1896, corrected by $+0^{s}\cdot028$ as above.

The adopted right ascensions for the 1872 and 1880 catalogues are the standard right ascensions given in the introductions to the 1872 and 1880 catalogues.

The adopted right ascensions for the 1860 and 1864 catalogues are the right ascensions given in these catalogues corrected as follows :—The standard right ascensions of the 1872 catalogue were carried back to 1860 and 1864 by means of Struve's precession and the Auwers-Bradley proper motions, and a comparison for each star made between these deduced places and those given in the 1860 and 1864 catalogues. The general mean was then found and taken out, and the resulting corrections were then formed for groups of 1^{h} of R.A., with weights corresponding to the number of observations. These corrections are given under the heading $\delta\alpha_{a}$ in the following table (a similar table will be found on p. 8 of the introduction to the 1872 catalogue, but depending on the proper motions then in use, which have been superseded by those of Auwers). After the applica-

tion of these corrections, δa_a, to the original differences the new quantities were again arranged in groups of 5° of N.P.D. with the same weights, and means formed. These values constitute the corrections depending on N.P.D., and are given under the heading δa_s in the following table. The extension of a group to more than 5° simply means that the several corrections under each 5° were practically identical. The resultant correction to be applied to the adopted catalogue places will be the algebraic sum of the two corrections, δa_a and δa_s.

Corrections to the Places of Clock Stars in the Greenwich 1860 *and* 1864 *Catalogues for Periodic Errors depending on Right Ascension and North Polar Distance* (δa_a *and* δa_s), *combined with Equinox Correction of* $-0^s{\cdot}004$ *to the* 1860 *Catalogue, and* $+0^s{\cdot}008$ *to the* 1864 *Catalogue derived from Greenwich* ⊙ *Observations* 1836–95.

R.A.	1860. s $\delta a_a - {\cdot}004$.	1864. s $\delta a_a + {\cdot}008$.	R.A.	1860. s $\delta a_a - {\cdot}004$.	1864. s $\delta a_a + 0{\cdot}012$.
h	s	s		s	s
0	+0·013	+0·024	12	−0·002	+0·012
1	+ ·011	+ ·018	13	− ·006	+ ·012
2	+ ·004	+ ·012	14	− ·014	+ ·008
3	− ·011	+ ·010	15	− ·015	+ ·007
4	− ·017	+ ·005	16	− ·012	+ ·003
5	− ·019	+ ·002	17	− ·011	+ ·001
6	− ·023	− ·005	18	− ·004	+ ·008
7	− ·026	− ·014	19	+ ·005	+ ·017
8	− ·025	− ·015	20	+ ·014	+ ·019
9	− ·022	− ·008	21	+ ·016	+ ·016
10	− ·016	− ·002	22	+ ·020	+ ·018
11	− ·008	+ ·004	23	+ ·019	+ ·024

1860. N.P.D.		1864. N.P.D.	
° °	s	° °	s
50–55	−0·036		
55–60	− ·030	50–65	−0·016
60–65	− ·023		
65–75	− ·006	65–75	− ·005
75–85	+ ·005	75–85	+ ·002
85–95	+ ·008	85–100	+ ·009
95–105	+ ·012	100–110	+ ·002
105–125	+ ·024	110–125	+ ·013

When necessary, the various catalogue places have been further corrected for any difference in the adopted proper motions (Auwers'), and those used in the catalogues.

Procyon has been specially corrected for orbital motion from Auwers' paper (*Ast. Nach.* 1371–2–3).

North Polar Distances.—These observations have been corrected to the following uniform system (*Mem. R.A.S.* vol. xlv.), viz.—Flexure=·00; formula for R—D $a+b \sin z$, virtually flexure, Bessel's refractions, and colatitude 38° 31′ 21″·90. This means that the north polar distances of the 1860 and 1864 catalogues have been increased by 0″·10 for colatitude, the value used in the catalogues being 21″·80. The north polar distances of the 1864 and 1872 catalogues have been corrected for R—D by the table given below, and those of 1872 have been further corrected by the table given at the end of the introduction to the 1872 catalogue itself to reduce them to Bessel's refractions and colatitude 21″·90. Like the right ascensions the N.P.D.'s have also been corrected for any differences in the adopted proper motions, and those used in the various catalogues. *Procyon* has also been pecially corrected for orbital motion (see above).

Table of corrections for R—D to reduce the observations 1862–1876 *to the system* $a+b \sin z$.

Year.	60°	70°	80°	90°	100°	110°	120°
	″	″	″	″	″		
1862	·00	−·03	−·11	−·19	−·30	−·37	−·40
3	·00	−·04	−·13	−·23	−·34	−·45	−·48
4	·00	−·02	−·09	−·16	−·24	−·32	−·34
5	·00	−·05	−·14	−·28	−·42	−·55	−·58
6	·00	+·05	+·14	+·29	+·43	+·57	+·60
7	·00	+·04	+·11	+·21	+·32	+·42	+·45
8	·00	+·05	+·17	+·32	+·49	+·64	+·69
9	·00	+·06	+·15	+·29	+·44	+·58	+·63
70	·00	+·04	+·14	+·26	+·39	+·51	+·55
1	·00	+·04	+·14	+·26	+·39	+·51	+·55
2	·00	+·03	+·10	+·19	+·30	+·39	+·42
3	00	+·04	+·11	+·22	+·33	+·43	+·46
4	·00	+·03	+·10	+·19	+·29	+·40	+·42
5	·00	+·02	+·06	+·11	+·18	+·23	+·24
6	·00	+·02	+·07	+·14	+·21	+·27	+·29

From the observations thus corrected and reduced corrections were obtained to the adopted proper motions, as is most easily explained by the following example. Columns (5) and (14) are deduced as follows:—The epoch corresponding to the mean of the group 1887–1896 is regarded as standard, and the number of years elapsed between the epoch and that of any other catalogue is the number of years on which the proper motion depends. In the same way columns (6) and (15) represent the differences of R.A. or N.P.D. between the R.A. and N.P.D. corresponding to the group 1887–1896 regarded as standard and the R.A. and N.P.D. at the other epochs. Columns (7) and (16), the weight, is derived from the expression $\frac{\text{no. of observations} \times \text{years}}{100}$. The remaining columns explain themselves.

Computation of Corrections to Auwers' Proper Motions.

α Andromedæ		Adopted P.M. $+^{s}\cdot0095$				Corrected P.M. $+^{s}\cdot0102$						Adopted P.M. $+''\cdot156$				Corrected P.M. $+''\cdot150$			
Catalogue.	R.A. 1890.	Date. 1800 +	No. of Obs.	No. of Years.	Diff. of R.A.	Wt.	No. of Obs. × Years.	Years × Wt.	Diff. of R.A. × Wt. +	Diff. of R.A. × Wt. −	N.P.D. 1890.	Date. 1800 +	No. of Obs.	No. of Years.	Diff. of N.P.D.	Wt.	No. of Obs. × Years.	Years × Wt.	Diff. of N.P.D. × Wt. + −
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)		(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
	h m s				s				s	s	° ′ ″				″				″
1860	0 2 42·063	57·8	89	35·4	+·024	21	20·89	743·4	·504		61 31 0·95	58·1	53	34·9	−0·24	18	...	628·2	4·32
1864	·052	64·8	56	28·4	+·035	15	15·92	454·4	·560		0·80	65·2	44	27·8	− ·09	12	...	333·6	1·08
1872	·074	71·7	62	21·5	+·013	13	13·33	279·5	·169		0·76	72·2	64	20·8	− ·05	13	...	270·4	·65
1880	·097	82·1	69	11·1	−·012	8	7·66	88·8		·096	0·86	81·7	42	11·3	− ·15	5	...	56·5	·75
1887–1896	·087	93·2	131					1566·1	1·233		0·71	93·0	100					1288·7	6·80
									·096										
									1·137										

$$\text{Correction} = \frac{+1^{s}\cdot137}{1566\cdot1} = +^{s}\cdot0007 \qquad \text{Correction} = \frac{-6''\cdot80}{1288\cdot7} = -''\cdot005$$

In the following table are given the deduced proper motions from the Greenwich Observations, as well as the corrections to Auwers' and Newcomb's systems of proper motions, where system of proper motion means the combined effect of precession, and what is generally termed proper motion.

Table of Proper Motions of the Greenwich Clock Stars from the Greenwich Transit Circle Observations 1854–1896, *and Corrections to Auwers' and Newcomb's Systems of Proper Motions.*

Star.	Approx. R.A.	Approx. N.P.D.	P.M. Right Ascension. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.	P.M. North Polar Distance. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.
	h m	° ′	s	s	s	″	″	″
α Androm.	0 3	61 31	+·0102	+·0007	−·0002	+0·150	−·006	−·019
γ Pegasi	8	75 26	+·0002	+·0009	+·0002	+ ·009	−·004	−·007
ι Ceti	14	99 26	−·0019	+·0013	−·0003	+ ·047	+·015	+·012
44 Piscium	20	88 40	−·0013	+·0015	+·0005	+ ·028	+·017	−·001
12 Ceti	24	94 34	+·0003	+·0006	−·0006	+ ·018	+·009	+·011
ε Androm.	33	61 17	−·0178	+·0006	−·0002	+ ·237	−·014	−·022
β Ceti	38	108 35	+·0154	+·0007	−·0003	− ·023	+·011	+·012
δ Piscium	43	83 1	+·0055	+·0020	+·0004	+ ·050	+·013	+·001
20 Ceti	47	91 45	+·0006	+·0028	+·0015	+ ·025	+·016	+·017
μ Androm.	51	52 6	+·0115	−·0026	−·0011	− ·034	+·015	−·010
ε Piscium	57	82 42	−·0056	+·0014	+·0002	− ·022	+·017	−·002
β Androm.	1 4	54 58	+·0144	·0000	+·0002	+ ·110	+·026	−·012
ζ¹ Piscium	8	83 0	+·0086	+·0011	−·0006	+ ·065	+·014	+·008
θ Ceti	19	98 45	−·0058	+·0010	+·0002	+ ·231	+·035	+·010
η Piscium	26	75 13	+·0017	+·0019	+·0007	+ ·006	+·003	−·002
ν Piscium	36	85 4	−·0013	+·0021	+·0005	+ ·002	+·007	+·001
ο Piscium	40	81 24	+·0043	+·0014	−·0003	− ·044	+·014	−·004
β Arietis	49	69 44	+·0067	+·0017	+·0007	+ ·105	+·003	−·009
α Arietis	2 1	67 3	+·0141	+·0014	+·0007	+ ·140	+·006	−·008
ξ¹ Ceti	7	81 40	−·0025	+·0007	−·0008	+ ·026	+·025	+·005
67 Ceti	12	96 56	+·0053	+·0017	+·0002	+ ·117	+·008	+·003
ξ² Ceti	22	82 2	+·0019	+·0008	−·0002	+ ·008	+·007	−·002
ν Ceti	30	84 53	−·0014	+·0037	+·0014	+ ·019	−·009	−·002
δ Ceti	34	90 9	−·0001	−·0005	−·0008	− ·021	−·028	−·019
γ² Ceti	38	87 14	−·0094	+·0020	+·0006	+ ·147	−·009	−·007
σ Arietis	45	75 22	+·0007	+·0009	−·0004	+ ·026	−·013	−·011
ε Arietis	53	69 6	−·0015	+·0010	−·0001	+ ·010	+·004	−·003
α Ceti	57	86 21	−·0005	+·0024	+·0007	+ ·081	+·008	−·002
δ Arietis	3 5	70 41	+·0104	+·0009	−·0001	+ ·005	+·010	+·003
τ¹ Arietis	15	69 15	+·0016	+·0008	−·0002	+ ·018	−·012	−·017
ο Tauri	19	81 22	−·0045	+·0007	+·0006	+ ·097	+·029	+·020

Star.	Approx. R.A.	Approx. N.P.D.	P.M. Right Ascension. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.	P.M. North Polar Distance. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.
	h m	° ′	s	s	s	″	″	″
f Tauri	3 25	77 26	+·0008	+·0010	−·0003	+·012	+·023	+·012
ε Eridani	28	99 50	−·0668	+·0007	−·0006	−·023	−·012	+·002
11 Tauri	34	65 2	+·0012	+·0014	+·0003	+·006	−·005	−·005
δ Eridani	38	100 8	−·0079	+·0002	−·0016	−·733	+·010	−·004
η Tauri	41	86 14	+·0017	+·0021	+·0005	+·041	+·001	−·011
γ¹ Eridani	53	103 49	+·0046	+·0017	+·0001	+·113	+·007	+·002
A¹ Tauri	58	68 13	+·0070	+·0017	+·0006	+·052	−·006	−·006
ω¹ Tauri	4 3	70 41	+·0072	+·0011	−·0002	+·032	−·001	−·013
o¹ Eridani	7	97 8	+·0003	+·0009	+·0001	−·090	−·005	−·006
γ Tauri	14	74 38	+·0080	+·0007	+·0002	+·014	−·016	−·013
ε Tauri	22	71 4	+·0084	+·0014	+·0008	+·018	−·010	−·016
Aldebaran	30	73 43	+·0052	+·0017	+·0012	+·178	−·006	−·011
τ Tauri	36	67 15	+·0004	+·0014	+·0003	+·025	+·016	+·007
μ Eridani	40	93 27	+·0011	+·0013	+·0002	+·014	+·012	+·004
ι Aurigæ	50	57 1	+·0010	+·0004	+·0001	+·014	+·011	−·006
ε Leporis	5 1	112 31	+·0020	+·0016	+·0009	+·042	−·026	−·021
Rigel	9	98 20	+·0007	+·0019	+·0009	−·007	−·002	−·007
β Tauri	19	61 29	+·0027	+·0014	+·0008	+·156	−·024	−·019
δ Orionis	26	90 23	+·0007	+·0021	+·0011	+·005	·000	+·004
α Leporis	28	107 54	−·0009	+·0002	−·0009	·000	+·010	·000
ε Orionis	31	91 16	+·0008	+·0026	+·0012	−·005	+·001	−·004
α Columbæ	36	124 8	−·0015	...	+·0021	...	...	...
κ Orionis	43	99 43	+·0009	+·0026	+·0011	+·005	+·009	+·002
α Orionis	49	82 37	+·0020	+·0012	+·0003	−·011	+·013	−·001
1 Geminor.	57	66 44	−·0011	−·0001	−·0008	+·108	+·015	+·002
ν Orionis	6 1	75 13	+·0001	+·0004	−·0007	+·043	+·030	+·021
η Geminor.	8	67 28	−·0057	−·0007	−·0013	+·006	+·003	−·008
μ Geminor.	16	67 26	+·0043	+·0006	+·0003	+·096	−·005	−·014
β Canis Maj.	18	107 54	−·0012	+·0003	−·0003	+·019	+·022	+·025
ν Geminor.	22	69 43	−·0002	+·0020	+·0009	+·011	+·005	−·001
γ Geminor.	31	73 30	+·0038	+·0015	+·0010	+·039	+·004	−·004
ξ Geminor.	39	76 59	−·0086	+·0001	−·0005	+·192	−·003	+·002
θ Canis Maj.	49	101 54	−·0096	+·0009	−·0004	+·033	+·030	+·029
ε Canis Maj.	54	118 49	−·0011	·0000	−·0007	−·005	+·012	+·002
ζ Geminor.	58	69 19	−·0016	−·0005	−·0009	−·009	−·008	−·012
γ Canis Maj.	59	105 28	−·0013	+·0005	−·0014	+·023	+·020	+·017
51 Geminor.	7 7	73 39	+·0006	+·0003	−·0009	+·034	+·001	−·004

Star.	Approx. R.A.	Approx. N.P.D.	P.M. Right Ascension. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.	P.M. North Polar Distance. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.
	h m	° ′	s	s	s	″	″	″
δ Geminor.	7 14	67 48	−·0017	+·0008	−·0002	+ ·008	+·011	−·003
β Canis Min.	21	81 29	−·0039	+·0003	−·0003	+ ·040	+·010	−·002
Castor	28	57 52	−·0138	+·0013	+·0011	+ ·089	+·010	+·011
Procyon	34	84 30	−·0464	+·0010	+·0012	+1·037	+·010	+·005
Pollux	39	61 42	−·0464	+·0017	+·0011	+ ·048	−·003	−·002
ξ Argus	45	114 35	−·0018	−·0007	−·0013	+ ·018	+·042	+·023
6 Cancri	57	61 54	−·0018	+·0007	−·0003	+ ·030	−·009	−·017
ρ Argus	8 3	113 59	−·0068	+·0007	−·0002	− ·043	+·018	+·014
β Cancri	11	80 28	−·0043	+·0001	−·0004	+ ·041	·000	−·007
d^1 Cancri	17	71 19	−·0042	+·0011	·0000	+ ·009	−·013	−·017
η Cancri	26	69 11	−·0030	+·0009	·0000	+ ·039	−·008	−·011
γ Cancri	37	68 8	−·0078	+·0009	−·0003	+ ·039	+·006	+·001
ε Hydræ	41	83 11	−·0132	+·0003	−·0001	+ ·051	+·028	+·007
α Cancri	52	77 43	+·0024	+·0014	+·0003	+ ·033	+·011	−·002
κ Cancri	9 2	78 53	−·0013	+·0015	+·0003	·000	+·009	−·007
83 Cancri	13	71 50	−·0089	+·0001	−·0010	+ ·123	−·016	−·007
α Hydræ	22	98 11	−·0016	+·0003	−·0002	− ·037	+·015	+·002
ξ Leonis	26	78 13	−·0068	+·0008	−·0002	+ ·095	+·035	+·017
ο Leonis	35	79 36	−·0103	+·0001	−·0005	+ ·027	+·009	·000
ε Leonis	40	65 43	−·0035	+·0008	+·0003	+ ·007	−·001	−·009
μ Leonis	47	63 29	−·0168	+·0017	+·0007	+ ·048	+·003	·000
π Leonis	54	81 26	+·0028	+·0012	+·0005	+ ·016	+·005	−·004
Regulus	10 3	77 30	−·0166	+·0016	+·0006	− ·010	+·008	−·004
γ^1 Leonis	14	69 36	+·0218	+·0010	+·0009	+ ·134	−·002	−·011
μ Hydræ	21	106 17	−·0103	−·0005	·0000	+ ·067	+·006	−·007
ρ Leonis	27	80 8	−·0010	+·0002	−·0003	− ·002	+·009	+·001
34 Sextantis	37	85 51	−·0065	+·0025	−·0004	− ·036	−·003	−·002
l Leonis	43	78 52	−·0008	+·0007	−·0022	+ ·028	+·008	+·001
d Leonis	55	85 48	+·0006	+·0024	+·0004	− ·005	−·017	−·021
χ Leonis	59	82 4	−·0235	+·0020	+·0002	+ ·034	+·012	·000
δ Leonis	11 8	68 52	+·0099	−·0003	−·0005	+ ·126	+·011	−·008
δ Crateris	14	104 11	−·0094	+·0012	−·0002	− ·197	+·012	+·004
τ Leonis	22	86 32	+·0008	+·0018	+·0003	+ ·013	+·007	+·003
υ Leonis	31	90 13	−·0003	+·0015	·0000	− ·056	−·009	−·011
β Leonis	43	74 49	−·0347	+·0009	−·0002	+ ·109	+·011	−·003
β Virginis	45	87 37	+·0492	+·0011	+·0002	+ ·267	+·005	−·002
π Virginis	55	82 46	−·0008	+·0020	+·0004	+ ·029	+·012	+·003

Star.	Approx. R.A.	Approx. N.P.D.	P.M. Right Ascension. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.	P.M. North Polar Distance. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.
	h m	° ′	s	s	s	″	″	″
ο Virginis	11 59	80 59	−·0155	+·0004	−·0004	−·040	+·009	−·001
ε Corvi	12 4	112 0	−·0067	−·0008	−·0012	−·005	+·016	+·003
η Virginis	14	90 3	−·0045	+·0011	−·0006	+·020	−·002	−·002
δ Corvi	24	105 54	−·0161	−·0019	−·0017	+·140	−·006	−·002
β Corvi	29	112 47	−·0017	+·0016	−·0006	+·057	+·005	+·002
ρ Virginis	36	79 9	+·0047	+·0014	−·0010	+·083	−·005	−·018
35 Virginis	42	85 50	−·0010	+·0020	−·0003	+·005	−·001	−·001
31 Comæ	46	61 52	−·0020	+·0007	+·0005	+·001	−·017	−·017
δ Virginis	50	86 0	−·0320	+·0016	+·0002	+·061	+·014	+·006
ε Virginis	57	78 27	−·0192	·0000	−·0002	−·023	+·006	−·002
θ Virginis	13 4	94 57	−·0034	+·0009	·0000	+·031	−·006	−·002
Spica	19	100 35	−·0025	+·0019	+·0008	+·037	+·019	+·011
ζ Virginis	29	90 2	−·0195	+·0010	+·0003	−·039	+·017	+·005
m Virginis	36	98 9	−·0076	+·0009	+·0001	−·036	+·010	+·002
τ Boötis	42	72 0	−·0345	+·0001	−·0001	−·033	+·007	−·003
η Boötis	49	71 3	−·0049	·0000	−·0003	+·354	+·010	−·004
τ Virginis	56	87 55	+·0007	+·0012	·0000	+·011	−·022	−·012
94 Virginis	14 0	98 21	−·0002	+·0030	+·0013	−·022	−·010	−·009
κ Virginis	7	99 46	−·0007	−·0003	−·0009	−·138	+·003	−·001
Arcturus	11	70 15	−·0781	+·0018	·0000	+1·989	+·012	−·011
f Boötis	21	70 17	−·0053	+·0004	·0000	−·026	+·003	−·006
ρ Boötis	27	59 9	−·0080	+·0005	−·0005	−·125	·000	−·007
ϵ^2 Boötis	40	62 28	−·0032	+·0011	+·0004	−·021	−·020	−·007
α Libræ	45	105 35	−·0076	+·0017	+·0007	+·071	−·001	·000
ξ^2 Libræ	51	100 58	−·0002	+·0017	+·0008	−·010	−·004	−·008
ψ Boötis	59	62 37	−·0126	+·0019	+·0008	−·001	−·009	−·012
ι^1 Libræ	15 6	109 22	−·0030	+·0007	+·0006	+·038	−·004	−·012
β Libræ	11	98 59	−·0072	+·0007	−·0002	+·020	+·003	−·001
σ^2 Libræ	17	104 44	−·0005	+·0020	+·0004	−·018	−·005	−·012
ζ^1 Libræ	22	106 20	−·0001	+·0009	−·0002	+·034	−·012	−·006
α Coronæ	30	62 55	+·0094	+·0009	+·0006	+·082	−·012	−·015
α Serpentis	39	83 14	+·0096	+·0017	+·0011	−·051	+·005	−·006
ε Serpentis	45	85 11	+·0089	+·0021	+·0011	−·059	·000	+·013
γ Serpentis	51	73 59	+·0213	+·0019	+·0004	+1·272	−·014	−·015
β^1 Scorpii	59	109 30	−·0023	+·0003	−·0006	+·011	−·016	−·014
δ Ophiuchi	16 9	93 25	−·0036	+·0013	−·0002	+·157	+·020	+·015
γ Herculis	17	70 35	−·0032	+·0017	+·0004	−·045	+·003	−·007

Star.	Approx. R.A. h	m	Approx. N.P.D. °	′	P.M. Right Ascension. Greenwich. s	Greenwich minus Auwers. s	Greenwich minus Newcomb. s	P.M. North Polar Distance. Greenwich. ″	Greenwich minus Auwers. ″	Greenwich minus Newcomb. ″
Antares	16	23	116	11	−·0009	+·0013	+·0003	+ ·046	+·018	+·017
λ Ophiuchi		25	87	46	−·0026	+·0001	−·0001	+ ·081	+·016	+·003
ζ Ophiuchi		31	100	21	+·0002	+·0009	·0000	− ·018	+·017	+·004
ζ Herculis		37	58	12	−·0365	−·0009	·0000	− ·385	+·025	+·007
κ Ophiuchi		53	80	27	−·0193	+·0019	+·0009	+ ·011	+·026	+·001
ε Herculis		56	58	55	−·0039	+·0008	−·0002	− ·039	−·007	−·015
η Ophiuchi	17	4	105	35	+·0023	+·0020	+·0011	− ·087	+·010	+·003
α^1 Herculis		10	75	29	−·0008	+·0011	+·0002	− ·042	−·012	−·014
θ Ophiuchi		15	114	53	−·0018	+·0006	−·0007	+ ·030	−·005	−·004
σ Ophiuchi		21	85	46	+·0009	+·0026	+·0011	− ·003	+·012	+·005
α Ophiuchi		30	77	22	+·0081	+·0015	+·0004	+ ·230	+·013	−·005
β Ophiuchi		38	85	23	−·0023	+·0018	+·0006	− ·157	+·010	−·001
μ Herculis		42	62	13	−·0248	−·0004	−·0009	+ ·727	−·018	−·024
89 Herculis		51	63	56	+·0009	+·0006	−·0001	− ·017	−·008	−·012
72 Ophiuchi	18	2	80	27	−·0032	+·0024	+·0015	− ·087	+ 002	−·003
μ Sagittarii		7	111	5	−·0004	+·0010	+·0005	+ ·013	+·014	+·010
η Serpentis		16	93	0	−·0377	+·0023	+·0004	+ ·707	+·030	+·023
λ Sagittarii		21	115	29	−·0053	−·0001	−·0015	+ ·184	−·014	−·020
α Lyræ		33	51	19	+·0183	+·0010	+·0007	− ·284	+·011	−·007
2 Aquilæ		36	99	9	+·0008	+·0012	−·0008	− ·004	+·001	−·013
β^1 Lyræ		46	56	46	+·0006	+·0013	+·0004	+ ·009	+·026	+·001
ε Aquilæ		55	75	5	−·0037	+·0012	+·0007	+ ·085	+·005	+·001
ζ Aquilæ	19	0	76	18	−·0003	+·0023	+·0007	+ ·096	+·007	−·008
ψ Sagittarii		9	115	27	+·0032	+·0028	+·0011	+ ·040	+·011	+·001
ω Aquilæ		13	78	36	·0000	+·0014	+·0005	− ·011	+·014	−·001
δ Aquilæ		20	87	6	+·0176	+·0023	+·0012	− ·081	+ 010	−·004
α Vulpec.		24	65	33	−·0092	+·0016	+·0006	+ ·103	+·001	− 011
μ Aquilæ		29	82	51	+·0145	+·0016	+·0003	+ ·155	+·022	+·005
h^2 Sagittarii		30	115	8	+·0029	+·0013	−·0011	+ ·021	+·011	−·011
e^1 Sagittarii		34	106	33	+·0027	+·0001	−·0014	+ ·038	−·001	−·014
γ Aquilæ		41	79	39	+·0010	+·0015	+·0005	+ ·004	+·012	−·003
α Aquilæ		45	81	25	+·0363	+·0012	+·0007	− ·372	+·012	+·001
β Aquilæ		50	83	52	+·0026	+·0019	+·0004	+ ·469	−·004	−·017
c Sagittarii		56	118	1	+·0020	+·0016	+·0001	− ·003	+·021	+·005
θ Aquilæ	20	6	91	9	+·0023	+·0024	+·0007	− ·011	+·003	−·010
α^2 Capricorni		12	102	53	+·0036	+·0014	−·0001	+ ·003	+·020	+·020
β Capricorni		15	105	8	+·0023	+·0015	−·0004	− ·002	+·020	·000

Star.	Approx. R.A.	Approx. N.P.D.	P.M. Right Ascension. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.	P.M. North Polar Distance. Greenwich.	Greenwich minus Auwers.	Greenwich minus Newcomb.
	h m	° ′	s	s	s	″	″	″
ρ Capricorni	20 23	108 11	−·0017	+·0011	+·0001	+ ·030	+·023	+·004
Σ Delphini	28	79 4	+·0001	+·0007	−·0003	+ ·027	+·005	−·003
α Delphini	35	74 29	+·0045	+·0014	+·0001	+ ·002	·000	−·011
ε Aquarii	42	99 54	+·0018	+·0020	+·0005	+ ·039	+·012	+·003
μ Aquarii	47	99 24	+·0027	+·0019	+·0005	+ ·030	−·001	−·015
32 Vulpec.	50	62 22	−·0003	+·0013	+·0001	− ·010	−·012	−·011
θ Capricorni	59	107 40	+·0057	+·0017	+·0010	+ ·066	+·012	−·006
ζ Cygni	21 8	60 13	+·0004	+·0019	+·0008	+ ·050	−·016	−·018
α Equulei	10	85 12	+·0043	+·0022	+·0013	+ ·088	+·010	−·003
ι Capricorni	16	107 18	+·0017	+·0020	−·0003	+ ·007	+·020	+·005
β Aquarii	26	96 3	+·0020	+·0026	+·0012	+ ·006	+·005	−·010
ξ Aquarii	32	98 21	+·0076	+·0018	+·0004	+ ·021	−·001	−·011
ε Pegasi	39	80 38	+·0011	+·0003	−·0001	− ·003	+·008	+·010
δ Capricorni	41	106 38	+·0171	+·0005	−·0001	+ ·313	+·016	+·010
16 Pegasi	48	64 36	−·0002	+·0003	−·0005	− ·009	−·011	−·009
α Aquarii	22 0	90 51	+·0006	+·0014	·0000	+ ·009	+·0 1	·000
ι Pegasi	2	65 12	+·0222	+·0013	+·0002	− ·043	−·023	+·028
θ Aquarii	11	98 20	+·0076	+·0019	+·0006	+ ·033	+·014	+·008
γ Aquarii	16	91 56	+·0075	+·0007	−·0002	+ ·002	+·019	+·011
σ Aquarii	25	101 14	−·0008	+·0003	−·0004	+ ·027	−·010	−·005
η Aquarii	30	90 41	+·0057	+·0015	+·0004	+ ·063	+·010	+·004
ζ Pegasi	36	79 45	+·0045	+ 0001	−·0007	+ ·010	−·008	−·011
μ Pegasi	45	65 59	+·0100	+·0004	−·0008	+ ·035	−·007	−·013
λ Aquarii	47	98 10	+·0005	+·0021	+·0007	− ·026	+·014	+·002
Fomalhaut	52	120 12	+·0249	+·0017	·0000	+ ·179	+·020	·000
α Pegasi	59	75 23	+·0037	+·0009	−·0001	+ ·036	+·006	−·010
γ Piscium	23 11	87 19	+·0499	+·0012	+·0001	− ·021	−·004	−·007
κ Piscium	21	89 20	+·0057	+·0016	+·0004	+ ·088	−·014	−·012
ι Piscium	34	84 58	+·0244	+·0010	+·0001	+ ·433	−·010	−·008
δ Sculptoris	43	118 44	+·0073	...	−·0021	+ ·137	...	+·003
ω Piscium	54	83 45	+·0097	+·0010	−·0002	+ ·107	−·001	−·006
2 Ceti	58	107 57	+·0009	+·0010	−·0002	+ ·026	+·031	+·006

The two following tables give the differences between the Greenwich system of proper motions and those of Auwers and Newcomb for each hour of right ascension, and for each 5° of N.P.D. from 60° to 120°. The first group extends to 10°, on account of the paucity of stars. Equal weight has been given to each star :—

Corrections to Auwers' and Newcomb's Systems of Proper Motions, arranged in order of R.A.

R.A.	No. of Stars.	P.M. in R.A. Gr.–A.	P.M. in R.A. Gr.–N.	P.M. in N.P.D. Gr.–A.	P.M. in N.P.D. Gr.–N.
h		s	s	"	"
0	11	+·00090	·00000	+·0082	–·0006
1	7	+·00131	+·00020	+·0145	–·0012
2	10	+·00143	+·00014	–·0003	–·0047
3	10	+·00112	–·00007	+·0043	–·0006
4	8	+·00111	+·00033	+·0001	–·0070
5	9	+·00150	+·00051	–·0004	–·0048
6	11	+·00046	–·00036	+·0100	+·0052
7	8	+·00068	+·00006	+·0083	+·0007
8	7	+·00077	–·00010	+·0060	–·0021
9	8	+·00081	–·00001	+·0074	–·0010
10	8	+·00124	–·00022	+·0032	–·0048
11	8	+·00108	–·00004	+·0073	–·0018
12	9	+·00063	–·00055	+·0013	–·0035
13	7	+·00086	+·00012	+·0050	–·0004
14	9	+·00131	+·00029	–·0029	–·0068
15	9	+·00124	+·00035	–·0059	–·0076
16	8	+·00089	+·00014	+·0147	+·0028
17	8	+·00123	+·00022	+·0002	–·0068
18	8	+·00129	+·00024	+·0094	–·0009
19	12	+·00163	+·00030	+·0098	–·0046
20	10	+·00154	+·00022	+·0082	–·0031
21	8	+·00145	+·00034	+·0038	–·0058
22	11	+·00112	–·00002	+·0042	–·0038
23	5	+·00116	+·00004	+·0004	–·0060

Corrections to Auwers' and Newcomb's Systems of Proper Motions, arranged in order of N.P.D.

N.P.D.	No. of Stars.	P.M. in R.A. Gr.–A.	P.M. in R.A. Gr.–N.	P.M. in N.P.D. Gr.–A.	P.M. in N.P.D. Gr.–N.
° °		s	s	"	"
50–60	10	+·00038	+·00009	+·0119	–·0051
60–65	15	+·00101	+·00024	–·0112	–·0130
65–70	21	+·00087	+·00004	+·0002	–·0037
70–75	17	+·00100	+·00008	–·0012	–·0088
75–80	23	+·00102	–·00010	+·0069	–·0009
80–85	26	+·00124	+·00018	+·0092	·0000
85–90	20	+·00183	+·00045	+·0024	–·0027
90–95	16	+·00144	+·00023	+·0066	+·0017
95–100	19	+·00148	+·00025	+·0060	–·0014

N.P.D.	No. of Stars.	P.M. in R.A. Gr.−A.	P.M. in R.A. Gr.−N.	P.M. in N.P.D. Gr.−A.	P.M. in N.P.D. Gr.−N.
° °		s	s	″	″
100–105	10	+·00117	−·00011	+·0107	+·0052
105–110	18	+·00071	−·00024	+·0089	+·0007
110–115	7	+·00057	−·00037	+·0084	+·0030
115–120	7	+·00117	−·00031	+·0107	−·0013
Mean	209	+·00112	+·00008	+·0050	−·0028

From the above comparison it would appear that the system of proper motions in Newcomb's new Fundamental Catalogue of Right Ascensions are practically identical with those that have been deduced as the Greenwich system of proper motions, while the correction to Auwers' system of proper motions indicates an erroneous epoch correction applied to the Bradley observations. With regard to the North Polar distances the Greenwich mean results stand almost midway between those of Auwers and Newcomb. There is a distinct run in the results both of R.A. and N.P.D. arranged in order of N.P.D., the error of which, on the average, for the Greenwich results would only amount to $\pm 0^{s}\cdot 01$ or $\pm 0''\cdot 12$ in the observed places at the extreme ranges. The result of the group in N.P.D. under the heading N.P.D. 60°–65° is distinctly anomalous, but most consistent. To hazard an explanation one would be inclined to suggest Bradley division errors.

In *Monthly Notices*, lvi. p. 6, I deduced the proper motions of some 45 fundamental stars from the Greenwich Observations, 1836–93; those in right ascension are affected by the systematic errors referred to above, and are not compared; but those in N.P.D., which are based on the same system of reductions, are compared in the following table, and the differences exhibited as corrections to Newcomb's system:—

Comparison between the Proper Motions in North Polar Distance derived from the Greenwich Observations, 1836–93 (*Monthly Notices,* vol. lvi. p. 6) (*Gr_{57}*), *and from the Greenwich Transit Circle,* 1854–96 (*Gr_{42}*).

Star.	Gr_{57}−N.	Gr_{42}−N.	Star.	Gr_{57}−N.	Gr_{42}−N.
	″	″		″	″
α Andromedæ	−0·013	−0·019	η Boötis	−0·006	−0·004
γ Pegasi	− ·003	− ·007	Arcturus	− ·006	− ·011
μ Andromedæ	− ·006	− ·010	ε² Boötis	− ·003	− ·007
β Andromedæ	− ·011	− ·012	α Coronæ	− ·003	− ·015
α Arietis	+ ·002	− ·008	ε Serpentis	− ·003	− ·006
α Ceti	− ·010	− ·002	ζ Herculis	+ ·005	+ ·007
Aldebaran	− ·005	− ·011	α Herculis	− ·002	− ·014
Rigel	− ·005	− ·007	α Ophiuchi	− ·004	− ·005
β Tauri	− ·010	− ·019	α Lyræ	+ ·002	− ·007
ε Orionis	− ·004	− ·001	β Lyræ	− ·001	+ ·001

Star.	Gr$_{87}$–N.	Gr$_{64}$–N.	Star.	Gr$_{87}$–N.	Gr$_{64}$–N.
Castor	+ $''$·013	+ $''$·011	γ Aquilæ	+ $''$·005	− $''$·003
Procyon	− ·005	+ ·005	α Aquilæ	+ ·009	+ ·001
Pollux	+ ·001	− ·002	β Aquilæ	− ·005	− ·017
Regulus	+ ·006	− ·004	α^2 Capricorni	+ ·016	+ ·020
β Leonis	+ ·006	− ·003	α Aquarii	− ·011	·000
Spica	+ ·002	+ ·011	α Pegasi	·000	− ·010
			Mean	− ·0015	− ·0049

Apparently the longer system of observations gives results more accordant with those of Newcomb, but the difference in mean results points to a certain amount of discordance between the transit circle and mural circle observations.

The results of this paper appear to confirm the theory that the greater accuracy of modern instruments counterbalances the advantages of the older observations in point of time, and afford evidence of the limits of accuracy which can be attained in determining proper motions from different groups of well observed star places.

Observations of Comet b 1898 (Perrine), made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log. Factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log. Factor of Parallax.	No of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1898. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
Apr. 15 14 42 16	B.	−2 4·61	−0·01	9·6805	−7 32·0	−0·3	0·7780	4	23 12 56·52	48 21 20·6	*a*
22 13 42 48	W.	+0 13·84	−0·01	9·6625	−4 7·4	−0·3	0·8313	6	23 48 51·04	43 42 7·3	*b*
22 14 2 44	S.	−0 18·15	+0·01	9·6826	+5 29·1	+0·3	0·8110	6	23 48 57·60	43 41 34·1	*c*
23 14 26 31	B.	−0 50·54	−0·01	9·7051	−5 43·0	−0·2	0·7833	3	23 54 20·68	43 5 56·0	*d*
23 14 31 32	,,	−0 12·05	+0·01	9·7084	+7 42·6	+0·3	0·7772	3	...	...	*e*
30 14 4 56	S.	+1 46·75	+0·01	9·7084	+7 1·2	+0·4	0·8042	8	...	...	*f*
30 14 4 56	,,	+1 14·77	0·00	9·7084	−0 13·9	0·0	0·8042	8	...	...	*g*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

Apr. 15.—The comet was bright with a fairly large nucleus, and a tail over $\frac{1}{2}°$ in length in north preceding direction.
Apr. 23.—The comet was still bright, but the tail was not so conspicuous as on Apr. 15.

The initials B., S., W. are those of Mr. Bryant, Mr. Showell, and Mr. Witchell respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1898·0. h m s	Assumed N.P.D. 1898·0. ° ′ ″	Authority.
a	10 Andromedæ	23 15 1·01	48 28 50·2	Greenwich Ten-year Catalogue 1890 (MS.).
b	O. A. (N.), 26141	23 48 37·13	43 46 13·6	Bonn Astr. Gesell. Catalogue.
c	Lal. 46852	23 49 15·67	43 36 3·3	,, ,, ,,
d	O. A. (N.), 26274	23 55 11·15	43 11 38·1	,, ,, ,,
e	B.D. + 46°, No. 4226	23 54 25	42 57	Bonn Observations, vol. v.
f	B.D. + 50°, No. 106	0 30 16	39 29	,, ,,
g	B.D. + 50°, No. 108	0 30 50	39 35	,, ,,

Royal Observatory, Greenwich:
1898 *May* 12.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVIII. JUNE 10, 1898. No. 8

SIR R. S. BALL, LL.D., F.R.S., President, in the Chair.

Henry Ellis, Little Heath, Potter's Bar;
Peter Matthews, 65 Gordon Mansions, W., and 102 Fenchurch Street, E.C.;
Captain P. B. Molesworth, R.A., Trincomali, Ceylon;
W. R. Reynolds, 61 Fairholt Road, Stamford Hill, N.; and
William Edward Sparkes, 5 Roker Terrace, Sunderland,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Lieutenant Tristan Dannreuther, R.N., F.R.G.S., H.M.S. *Leander*, Pacific Station, Esquimault, British Columbia (proposed by S. Wellesley Johnson); and
Charles Thomas Whitmell, M.A., B.Sc., H.M. Inspector of Schools, Invermay, Headingley, Leeds (proposed by G. A. S. Atkinson).

The following were proposed by the Council as Associates of the Society :—

O. Backlund, St. Petersburg;
Edward Emerson Barnard, D.Sc., F.R.A.S., Yerkes Observatory, U.S.A.;

Sherburne Wesley Burnham, M.A., F.R.A.S., Government Building, Chicago, U.S.A.;

Lieut.-Col. G. Defforges, Service Géographique de l'Armée, Paris;

James Edward Keeler, D.Sc., F.R.A.S., Director of the Lick Observatory, Mount Hamilton, California, U.S.A.;

Henry A. Rowland, Johns Hopkins University, Baltimore, Md., U.S.A.;

Wilhelm Schur, Observatory, Göttingen, Germany.

Seventy-five presents were announced as having been received since the last meeting, including, amongst others:—

W. T. Lynn, Remarkable Eclipses, 3rd edition; F. McClean, Comparative photographic spectra of stars to the $3\frac{1}{2}$ mag.; and Comparison of oxygen with spectra of Helium stars and summary of spectra of southern stars, presented by the authors. Galileo, Opere, edizione nazionale, vol. vii., presented by the Italian Government; Laplace, Œuvres complètes, tome xii., presented by the Paris Academy; L. Weinek, Photographischer Mond-Atlas, Heft 1, 2, presented by Dr. Weinek; Old transit instrument, formerly belonging to Dr. Longfield of Cork, presented by Miss Lecky, executrix of the late R. J. Lecky, F.R.A.S.

Publication of Eclipse Results.

The question of the publication of the reports of the observers sent out by the Joint Permanent Eclipse Committee of the Royal and Royal Astronomical Societies has been under consideration by that Committee and by the Councils of the two Societies which it represents; and by the generosity of the Royal Society a very satisfactory solution has been arrived at. The main difficulty lay in the choice of the series of publications: if the reports were communicated, as on other occasions, to the Royal Society, it was felt that they would not be easily accessible to many astronomers; while if, on the other hand, they were printed in the publications of this Society they would not be sufficiently brought to the notice of physicists and others. To print them in both series would have obvious disadvantages from the point of view of economy.

The solution arrived at is as follows: The Preliminary Reports are to be printed in the *Proceedings of the Royal Society.* After the usual copies have been struck off for the use of Fellows of the Royal Society, the printers will then be directed to strike off one thousand copies more, altering merely the paging to a series of figures in brackets—(1), (2), &c.—so that the reports

may appear as an Appendix to a volume of the *Monthly Notices* [the sizes of the pages in *Proc. R.S.* and *Monthly Notices* are almost the same], the extra expense of this one thousand copies being borne by this Society. Fellows of this Society may expect to receive this Appendix during the present summer for inclusion in the present volume of *Monthly Notices.*

As regards the full and final reports these will be printed as a volume of *Philosophical Transactions of the Royal Society*, and copies of this volume will be presented by the Royal Society to our Fellows who apply for them, and to such observatories, institutions, &c. as receive copies of our Memoirs.

It may be added that our Council have referred to the J.P.E. Committee the question whether it would not be desirable to invite other observers than those sent out by the Committee to communicate their results for publication along with these final reports in the volume of *Philosophical Transactions.*

H. F. Newall, }
H. H. Turner, } *Secretaries.*

Reply to Dr. Rambaut's Note "On the Effect of Chromatic Dispersion." By David Gill, C.B., F.R.S., Her Majesty's Astronomer at the Cape of Good Hope.

In the *Monthly Notices* for 1898 March Dr. Rambaut communicates a long and elaborate note on a previous paper of mine entitled "On the Effect of Chromatic Dispersion of the Atmosphere on the parallaxes of *a Centauri* and *β Orionis.*"

I desire before entering on any criticism of this note to acknowledge the value of Dr. Rambaut's original paper in so far as it suggests the desirability of expressing the possible effect of chromatic dispersion on parallax researches; and indeed I have acknowledged the value of that suggestion not only in my original paper, but in the best manner in my power, viz. by adopting it. In the determinations of stellar parallax, which I have since published, I have given the effect of chromatic dispersion in terms of $\Delta\beta$ on the result, or, when the observations admitted of it being done, I have determined the special value of $\Delta\beta$.

In no case, however, has $\Delta\beta$ proved to be a sensible quantity.

The point in Dr. Rambaut's original paper, which I was compelled to dispute, was the conclusion that my results were affected by a systematic error following the law of the effect of chromatic dispersion. Had such an error existed to the extent which Dr. Rambaut's discussion professed to show (viz. $\Delta\beta=0''\cdot095$, with factors of $\Delta\beta$ ranging from $-2\cdot3$ to $+0\cdot7$, producing systematic errors amounting to $+0''\cdot2$ and $-0''\cdot07$) I should certainly have been guilty of extreme want of circumspection in having over-

looked them; and if such systematic errors had really existed, the gravest doubt would be thrown on the reliability of all refined determinations of solar or stellar parallax.

I believed, and I still hold, that in my original paper I conclusively proved that the corrections $x_{,}$ $x_{,,}$ $x_{,,,}$ and $x_{,,,,}$ were due to real subjective errors, and that the true value of $\Delta\beta$ derivable from the observations of *a Centauri* is quite insensible (viz. $-0''\cdot015$ with the probable error $\pm0''\cdot059$), and that my original value of the parallax of *a Centauri* remains unchanged.

In support of his original contention, however, Dr. Rambaut proceeds to make the following statements, which I quote and designate for brevity as follows :—

(*a*) "It has always seemed to me most unsatisfactory to assume empirical corrections to remove the larger residuals and then, appealing to the smallness of the resulting residuals as a proof of the accuracy of the observations, to compute the probable error of the result by means of these reduced residuals."

(*b*) "It is a mistake in principle to assume the existence of constant errors unless one is absolutely driven to it."

(*c*) "The fact of an error of the same sign affecting a number of observations in a series does not prove it to be a constant, and in assuming it to be so we assume not only its magnitude, but also the law of its operation."

(*d*) "If we assume the existence of constant but unknown errors, and apply corrections for them, we must not ignore the fact that they are *errors*, and we must therefore include them in computing the probable error of an observation."

(*e*) "The irregular errors of observation are just as *real* as the systematic errors, and until we are assured that the latter are really constant, or until we have established the law of their operation, we must treat them as being subject to the law of frequency of errors, and take them into account in estimating the probable error of the result."

Now all these statements excepting (*b*) are quite incontrovertible. I fully grant their truth, and only contend that neither in my original discussion of the parallax of *a Centauri* (*Mem. R.A.S.* vol. xlviii.) nor in my subsequent one (*Monthly Notices*, vol. lviii. p. 63) have I omitted to regard them.

With regard to (*b*), however, I would prefer to render it as follows :—

"In every refined investigation in which the conditions of observation are in any way systematically changed the astronomer must take the greatest care to ascertain whether such systematic change in the conditions of observation is accompanied by a corresponding change in the results, and should so arrange

his observations as to afford the data necessary for a complete discussion of the law of such systematic error and for the computation or elimation of its effects."

I think there are very few experienced astronomers who will deny the soundness of this statement, or who will not agree that the danger of neglecting such precaution is likely to lead to erroneous conclusions.

In replying to Dr. Rambaut's criticism I shall therefore confine myself to two points.

1st. That my observations were affected by true systematic errors, and that these errors were traced to their true source, viz.—to four *true* constant subjective errors due to the four different conditions of measurement.

2nd. That the method employed to compute the necessary corrections and the probable error of the resulting parallax was the only accurate one.

First, then, what are the conditions which distinguish true systematic errors from those which are accidental, or which distinguish between legitimate and empirical corrections?

Primarily, of course, it is necessary to regard any physical source of possible error (such, for example, as Dr. Rambaut's $\Delta\beta$ with the factor $\tan\zeta\cos(p-q)$) as a legitimate unknown quantity which may properly be introduced into the equations. But besides such obvious possible sources of error, there may be others which are personal or subjective, *provided that the conditions of observation are changed.*

It is, of course, open for Dr. Rambaut to deny that this is the case. In his statement (*b*) he expresses his unwillingness to assume the existence of constant errors unless absolutely driven to it. This seems to me a very strange statement for any experienced astronomer to make. In my opinion it rather becomes the astronomer who aspires to obtain truthful results to be continually on the outlook for sources of possible systematic error.

If Dr. Rambaut had any experience of refined heliometer observations it would perhaps be easier to convince him. If, for example, he had made heliometer observations, without the aid of a reversing prism, of the angle between a distant star (50′ or 60′) and one of the components of a fairly close double star at very various hour-angles, and on opposite sides of the meridian, he would instinctively feel that, in pointing on such an unsymmetrical object, he could not be certain that his observations were unaffected by personality depending on the hour-angle or on the direction of measurement with respect to the observer's eyes.

As a proof of the general existence of such an instinctive feeling, and of the necessity for optical symmetry and constancy in apparent direction of measurement in his work, every careful

modern heliometer observer has now adopted the use of the reversing prism which I first introduced in my heliometer observations of *Mars* in 1877.

Had the reversing prism been employed in the observations of *a Centauri* in question much labour would have been saved, because the necessity for measures to determine the systematic corrections dependent on the direction of measurement with respect to the eyes of the observer would have been avoided.* But I was careful to make the special observations necessary to determine these systematic errors, discussed them, and believed that astronomers generally had adopted my conclusions as sound. Dr. Rambaut has denounced these corrections as *empiric*, and comes to the conclusion that my so-called empiric corrections can in reality be traced to a true physical origin, viz. chromatic dispersion of the atmosphere. This is at least his original contention, which provoked my criticism, and he has not yet admitted his error. Let me show once more, and if possible more forcibly, that Dr. Rambaut entirely fails to prove his thesis. Dr. Rambaut says "that Dr. Gill's argument founded on a comparison of the means of the residuals in each group is of *absolutely no value whatever*, his solution being artificially constructed to fulfil the condition that these means should each be zero." The latter part of this statement is perfectly true; but I have never employed any such argument, and it hardly required nearly two pages of algebra to show the self-evident fact that my small mean residuals of the groups in the fourth place of decimals only go to demonstrate the general arithmetical accuracy of work which was computed to three decimal places only.

But in examining the accuracy of Dr. Rambaut's solution it was surely reasonable and fair that I should divide the residuals of his solution into four groups corresponding to the four circumstances of measurement. If with the introduction of his $\Delta\beta$ in place of my $x_{\prime}\ x_{\prime\prime}\ x_{\prime\prime\prime}\ x_{\prime\prime\prime\prime}$ Dr. Rambaut had succeeded in representing all these groups of equations within reasonable limits of error, then he would have triumphantly proved his point, viz. shown that my $x_{\prime}\ x_{\prime\prime}\ x_{\prime\prime\prime}$ and $x_{\prime\prime\prime\prime}$ were unjustifiable empirical corrections, and that his value of $\Delta\beta$ was a true quantity. Unfortunately for Dr. Rambaut's argument, such is not the case.

Take the group 3, the largest group, containing 41 equations: *all* his residuals in this group, with three very small exceptions (viz. $+0^{R}\cdot007$, $+0^{R}\cdot007$, and $+0^{R}\cdot005$), are negative, the mean value being $-0^{R}\cdot0139$.

Now Dr. Rambaut finds, from his own solution, that the probable error of a single observation is $\pm0^{R}\cdot0131$; in other words, *the mean residual in this group of* 41 *observations is greater than*

* The reasons which compelled me very reluctantly to abandon the use of the reversing prism are given (*Mem. R.A.S.* vol. xlviii. p. 11), and need not be here repeated.

the probable error of a single observation ! ! If this fact alone does not prove the existence of a systematic error, and the neglect of a true systematic correction of some kind in Dr. Rambaut's solution, I think it will be difficult indeed to convince him ! The chance that the mean residual of a group of 41 observations, unaffected by systematic error, shall exceed the probable error of one observation is about the same as that in tossing a coin "heads" will come up 41 successive times or "tails" 41 successive times.

Has Dr. Rambaut considered what are the chances of tossing 41 successive "heads" ? If so, he will have determined the chances in favour of the truth of this part of his solution.

In group 4, which consists of 13 observations, Dr. Rambaut's mean residual is $+0^{R}\cdot0246$, so that the mean value of the residuals of 13 observations is nearly double the probable error of a single observation ! ! Further comment is unnecessary.

Turning now to my own solution. Dr. Rambaut questions "the validity of Dr. Gill's method of introducing constant corrections to smooth down the roughness of the observations, unless he takes into account the hypothetical character of these corrections in estimating the probable error of the result."

Here, again, Dr. Rambaut is in principle perfectly correct, but absolutely wrong as to his description of the reasons which led me to adopt the corrections in question. Before making such a statement, he should have carefully considered the circumstances which led me to the conclusion that the corrections in question were true subjective constant errors, due to the unsymmetrical character of one of the objects under observation. These circumstances are all fully detailed in my original memoir. First of all, I was fully aware of the possible effect of change of conditions of measurement, because, as early in the series as it was possible to do so, I began to make observations in the early morning as well as in the evening, so as to determine whether any such systematic differences existed. The immediate reduction of the observations showed that such errors really existed, and there was even then strong evidence that these errors were very closely dependent on the direction of measurement with respect to the line joining the eyes of the observer, so that careful note was made of this direction in the subsequent measures (*loc. cit.* p. 17). But I was careful not to assume this to be the case. In his criticism of the "hypothetical character of these corrections" Dr. Rambaut entirely omits to note the great care which I took to ascertain whether these errors were really constants or functions of the hour-angle, viz. by making and discussing my Solution III., in which, instead of assuming the corrections to be constants, they are expressed in the form—

$$x + \cos(p-q)\,\alpha + \sin(p-q)\,\beta + \cos 2(p-q)\,\gamma + \sin 2(p-q)\,\delta$$

(*loc. cit.* p. 35 *et seq.*).

This solution led to a value of the parallax practically identical with that of Solution I., but with a rather larger probable error for the single observation, tending to show that the errors are more nearly constants than functions of the hour-angle. This conclusion is, however, very much strengthened if we arrange the residuals of Solution III. in order of hour-angle in the same manner as those of Solution I. are given in my paper, ***Monthly Notices***, vol. lviii. pp. 59–62. Then we find that in group 1 the residuals begin at $8^h\ 17^m$ S.T. with a negative tendency, but become all positive towards the end of the first group; then in the immediately following group 2 the residuals suddenly change, and are chiefly negative in sign. What is the cause of this sudden change? Why, assuredly the change depending on the change of direction of measurement with relation to the line joining the eyes of the observer—there is nothing else to account for it. Passing from group 2 to group 3 there again occurs a sudden change in the sign of the residuals from negative to positive, showing that *no correction which is a function of the hour-angle will satisfy the observations*! Again in group 3 the residuals in the early part of the group are all positive, and nearly all negative towards the end, and then in the immediately following group 4 there is a sudden change towards the positive residual.

On the other hand if we take my Solution I., in which the corrections are assumed to be constants, we find that the positive and negative residuals are most fairly distributed throughout each group, notwithstanding the large range of hour-angle in each.*

If these are not valid proofs that the necessary corrections are true constants then I am unable to understand what valid proofs are.

These proofs contrast very favourably with the extraordinary solution originally proposed by Dr. Rambaut in which in a group of 41 successive equations (the order being that of the magnitude of the factor of a term the existence of which he is seeking to prove) 38 of the residuals have the same sign, and the mean residual exceeds the probable error of a single observation; or in another group of 13 observations, in which his mean residual is double his probable error for a single observation.

Again if we take group 3 of my Solution I. we find that the factors of $\Delta\beta$ vary from $+0{\cdot}18$ at the beginning to $-0{\cdot}98$ at the end of the group; but there is no evidence amongst my 41 residuals of any systematic tendency to increase or diminish from one end of the group to the other, as must necessarily be the case if $\Delta\beta$ were a sensible quantity.

Similarly, in group 4 the factors of $\Delta\beta$ vary from $-1{\cdot}08$ to $-2{\cdot}39$; and here again we find in the run of my residuals no

* If Dr. Rambaut should reply to this paper I trust he will avoid the mistake he previously made, and note that this argument refers to the run of the residuals in each group with reference to hour-angle in the group itself, and not to the agreement of the mean residuals of the different groups.

indication in the character of the residuals which points to a real value of $\Delta\beta$.

Besides all this I have given the more general solution (*Monthly Notices*, vol. lviii. p. 63), in which I have introduced Dr. Rambaut's $\Delta\beta$ as an unknown quantity, and derived its value, viz. $-0''\cdot015$ with the probable error $\pm0''\cdot059$. It has therefore no proved reality, and its most probable value has the opposite sign to that found for it by Dr. Rambaut.

I think it is hardly worth while to discuss irrelevant abstract statements such as "if Dr. Gill will allow me eight such corrections I can reduce the residuals so that none of them will exceed $0^{R}\cdot010$; twelve such corrections will reduce them all below $0^{R}\cdot005$, &c." . . .

I must point out to Dr. Rambaut that in the discussion of astronomical data common sense and a reasonable use of the critical faculty are absolutely necessary. If there were twelve *a priori* common-sense reasons for the introduction of 12 constants in a discussion of an investigation of stellar parallax it might be desirable to introduce the whole of them. But, of course, such corrections must not be assumed without some valid reason, such as a change in the method of observation or some instrumental change, or change in some external physical condition; and it would be necessary to determine by careful discussion—such as I have given in the case of *a Centauri*—whether the corrections are real and are truly constant or demonstrably follow some other law. Dr. Rambaut would also find that the introduction of 12 unknown constants would so reduce the weight of his resulting parallax as to make it quite indeterminate.

It is true that Dr. Rambaut states (page 259), "I do not for a moment mean to imply that a solution of this sort" (the introduction of arbitrary corrections)* "is comparable with Dr. Gill's, where his groups were arranged for him by considerations as to the position of the observer's head with regard to the line joining the stars. I merely intend to point out how misleading an appeal to the smallness of the residuals is in such a solution." I have nowhere stated that the smallness of the residuals should alone be appealed to in such a case; on the contrary, in the illustration which I gave from the discussion of my observations of β *Orionis* I have only introduced the unknown quantities $\Delta\beta$ and π, the existence of which were physically possible, and the introduction of either or both of these quantities *reduced* the sum of the squares of the residuals, but has *augmented the square of the mean error of a single observation.*

On these grounds I held that the values of $\Delta\beta$ and π were most probably insensible.

It is true that I have pointed out (page 57) that "it is a suspicious fact that the weight of an observation by Dr. Rambaut's solution is reduced to less than one half of that from my Solution I."

* The words in parenthesis are mine, and inserted for explanation.

Dr. Rambaut tries to force this statement into an expression that my chief grounds of objection to his solution are that the residuals are increased; whereas the real and solid ground of my rejection of his result is based on the fact that there is no correspondence whatever between his residuals and the coefficients of the term which he has introduced for the purpose of bringing the observations into systematic accord.

How does he account for the *sudden* systematic change of sign in his residuals from one group of observations to the next? That is the real question; that is the point which he studiously avoids, and endeavours to cover by a cloud of formulæ relating to a side issue.

These are my arguments, to which I am most anxious that Dr. Rambaut should reply; and I ask him to state, after he has examined them, whether he still finds that his $\Delta\beta$ has a real value approaching the probable error of a single observation. This was his original contention. If Dr. Rambaut had proved his point it would have thrown the gravest doubts on all previous investigations of stellar and planetary parallax; as it is, I find, from every point of view, that his solution is absolutely worthless, and entirely fails to represent the observations, and that the more closely the details and results of my own discussion are examined, the more fully do they prove the truth of my original solution.

Before entering on the entirely new contention which Dr. Rambaut has dragged into the discussion, viz. that my computation of the probable error of my result is erroneous, it seems necessary to clear the ground somewhat.

The general equation under consideration is of the form

$$x + by + cz = n,$$

where y is a term depending on the time, and z a term depending on the parallax.

The point where Dr. Rambaut is in error is as to the true meaning of x in his discussion. The term x is apparently interpreted by Dr. Rambaut to mean "the true correction to the assumed difference between the two measured distances α and β freed from parallax at the adopted epoch."

Therefore Dr. Rambaut says, if I follow him rightly, that if the observations are of four different kinds, or made under four different conditions of observation, each of which is affected by a constant error, then the equations will divide themselves into four groups of the following types:—

$$\begin{array}{lll} \text{Type} & \text{I.} & x + a_1 + b_1 y + c_1 z = n_1 \\ \text{,,} & \text{II.} & x + a_2 + b_2 y + c_2 z = n_2 \\ \text{,,} & \text{III.} & x + a_3 + b_3 y + c_3 z = n_3 \\ \text{,,} & \text{IV.} & x + a_4 + b_4 y + c_4 z = n_4 \end{array}$$

and he proceeds very elaborately to point out how the true weights and most probable values of x, a_1, a_2, a_3, a_4, y, and z should be determined.

The initial error which Dr. Rambaut has made, and which vitiates the whole of his subsequent conclusions, is his assumption that x is a true determinable constant independent of a_1, a_2, a_3, and a_4. This would only be true if we could *a priori* assume some relation between the values of a_1, a_2, a_3, and a_4, or that $a_1+a_2+a_3+a_4=$a known quantity. But as no such relation is known, it is only possible to determine from these equations $(x+a_1)$, $(x+a_2)$, $(x+a_3)$, $(x+a_4)$, y and z; for which I have written for simplicity $x_{,}$, $x_{,,}$, $x_{,,,}$, $x_{,,,,}$, y and z.

In other words our four groups of observations supposed to be affected by four constant but unknown sources of systematic error cannot yield a true value of x (in the sense in which I have defined it), because the mean of all our observations (apart from terms in y and z), or the means of our four derived values of the systematic errors, cannot be assumed to be free from systematic error. Our problem fortunately does not require a determination of x, but merely of $x_{,}$, $x_{,,}$, $x_{,,,}$, and $x_{,,,,}$, as I have defined them. I have already, in the earlier part of this paper, shown *that within the limits of the small accidental errors of observation, the systematic errors of the four groups cannot be represented by any continuous function of the hour-angle*; they are therefore true constants, and therefore also $x_{,}$, $x_{,,}$, $x_{,,,}$, and $x_{,,,,}$ are true constants. Being true constants there is but one legitimate method of determining $x_{,}$, $x_{,,}$, $x_{,,,}$, and $x_{,,,,}$, viz. to treat them as true unknown quantities, and to determine their values, weights, and probable errors by the usual Gaussian method of least squares simultaneously with the values, weights, and probable errors of y and z.

The results are given on page 28 of my original memoir.

I am quite at a loss to understand such statements as the following in Dr. Rambaut's paper:—"But in any case if we assume the existence of constant but unknown errors, and apply corrections for them, we must not ignore the fact that they are *errors*, and we must therefore include them in computing the probable error of an observation. This Dr. Gill has not done, and the computed probable error of his result is consequently very much underestimated. In his recent paper Dr. Gill argues with regard to these corrections that they represent real quantities, with the implication that if this is the case they need not be taken into account in calculating the probable error."

Every competent person will admit the truth of the first part of this statement, but I should be glad to be informed where I have implied that in computing the probable error of the parallax or of the unknown corrections the errors of the determinations of these corrections should not be taken into account. My original normal equations (omitting the term depending on the square of the time) were :—

$$
\begin{array}{lllllllll}
24{\cdot}50x_{,} & & & & +\ 8{\cdot}04y & +\ 6{\cdot}86y' & +15{\cdot}99z & = & +2{\cdot}16 \\
 & +13{\cdot}00x_{,,} & & & +\ 7{\cdot}99 & +\ 8{\cdot}35 & +\ 9{\cdot}32 & = & +0{\cdot}99 \\
 & & +37{\cdot}00x_{,,,} & & +12{\cdot}61 & +18{\cdot}82 & -\ 8{\cdot}69 & = & -1{\cdot}78 \\
 & & & +12{\cdot}00x_{,,,,} & +\ 2{\cdot}71 & +\ 2{\cdot}53 & -\ 6{\cdot}64 & = & -0{\cdot}62 \\
8{\cdot}04 & +\ 7{\cdot}99 & +12{\cdot}61 & +\ 2{\cdot}71 & +36{\cdot}56 & +37{\cdot}32 & +14{\cdot}95 & = & +1{\cdot}42 \\
6{\cdot}86 & +\ 8{\cdot}35 & +18{\cdot}82 & +\ 2{\cdot}53 & +37{\cdot}52 & +47{\cdot}59 & +11{\cdot}11 & = & +0{\cdot}84 \\
15{\cdot}99 & +\ 9{\cdot}32 & -\ 8{\cdot}69 & -\ 6{\cdot}64 & +14{\cdot}95 & +11{\cdot}11 & +48{\cdot}42 & = & +5{\cdot}65
\end{array}
$$

Now the coefficient of z (the term depending on the parallax) in the normal for z of these equations is 48·42; and if we neglect the errors of the determination of $x_{,}$, $x_{,,}$, $x_{,,,}$, $x_{,,,,}$, and y, the weight of z would necessarily be 48·42. If, in computing the weight of z, we have regard to the error of x and y, but disregard the effect of the errors of determination of the systematic corrections—in other words, if we add all the normals in $x_{,}$, $x_{,,}$, $x_{,,,}$, and $x_{,,,,}$, and treat the normal so formed as an equation in x, we obtain z with the weight 42.

But if we eliminate z with its weight from the whole of the six normal equations, we find the weight of z to be diminished from 42 to 22, in consequence of the effect of the errors of the determination of the other unknown quantities; and this is, of course, the true weight of z.

Also in computing the square of the mean error, instead of dividing the sum of the squares of the residuals by the number of equations, the sum is divided by the number of equations *minus* the number of unknowns. So far as I am aware, there is no other legitimate method of proceeding. The method is too well known to require further discussion or justification.

In conclusion, I may briefly criticise the five solutions, the results of which are summarised by Dr. Rambaut on page 279.

(1) Solving without regard to the systematic differences of the four different kinds of observation.

$$\pi = 0''{\cdot}819 \pm 0''{\cdot}014.$$

Dr. Rambaut admits that the residuals show this solution to be inadmissible, and the deduced parallax is much too large. This is pointed out on page 23 of my original memoir. On what ground is Dr. Rambaut's original solution then to be accepted, where the residuals are just as large and as systematically discordant? The comparatively small probable error of the result is due to the large algebraic weight of z.

This solution is a good illustration of the errors into which an astronomer would fall who persistently refuses to "assume the existence of constant errors unless absolutely driven to it."

(2) and (3) Dr. Rambaut's method of solving, by which

$$\pi = 0''{\cdot}769 \pm 0''{\cdot}014 \text{ and } \pi = 0''{\cdot}780 \pm 0''{\cdot}018.$$

The initial error of this solution is, as already shown, Dr. Rambaut's erroneous assumption that x is a real quantity—which assumption forces him to solve the equation in four different groups. He appears to overlook the fact that he cannot derive the most probable values of $x_{,}$, $x_{,,}$, $x_{,,,}$, and $x_{,,,,}$ by this process from a first approximation, because their resulting values depend on values of y and z which are not the definitive values of these quantities. To obtain a nearer approximation to the truth he would require to make a second approximation, employing in it the values of y and z derived from their four values combined with regard to their weights. Introducing these more approximate values of y and z, having regard to their probable errors as affecting the weights, he could make a second solution, and so on for a third and fourth approximation; whence he would finally arrive at the same most probable values of the unknowns and their true weights and probable errors, which I found by the more direct process.

(4) Dr. Rambaut's original solution, introducing $\Delta\beta$ and excluding personal errors,

$$\pi = 0''.780 \pm 0''.018.$$

This solution does not represent the observations any better than solution (1), which Dr. Rambaut himself condemns. The probable error of the single observation is just as great as in solution (1), and the systematic errors of the groups just as large, indeed larger.

This is the solution in which the mean residual of forty-one successive observations (arranged in order of hour-angle) is greater than Dr. Rambaut's own computed probable error of a single observation.

(5) My own solution

$$\pi = 0''.747 \pm 0''.013$$

alone is rational and complete.

The main point of my original paper, and of this one also, however, is that the true value of Dr. Rambaut's $\Delta\beta$ is entirely insensible, and therefore that chromatic dispersion has quite an insensible effect on my derived parallax of *α Centauri*.

Royal Observatory, Cape of Good Hope:
1898 *May.*

Note concerning Diffraction Phenomena, &c. By H. F. Newall, M.A.

I regret that my effort to make my note (*Monthly Notices*, lviii. [present volume], p. 3) as short as possible has led Mr. Wadsworth to think that I have done injustice to his work by the appearance of wholesale criticism. I had hoped to guard against this appearance by the explicit reference which I made to "results obtained with large and small reflectors and refractors"; and I cannot think that my intention was generally misunderstood. I am only sorry that a great press of business before leaving for India last winter made me forget my original intention of sending my note in manuscript to Mr. Wadsworth.

I am unwillingly led to believe that silence on my part now would be misunderstood. But I have little or nothing to add to what I have already said, except perhaps that it would not occur to me to interpret the paragraphs in the *Encyclopædia Britannica* in the way that Mr. Wadsworth has done. The lines quoted by him cannot be regarded as the *conclusion* of a line of argument, as Mr. Wadsworth represents them to be (*Astrophysical Journal*, vii. p. 79); on the contrary they form the introduction to a very elegant treatment of a special example of illumination near the border of an image; and, though they contain statements which are not rigorously consistent, the meaning is beyond doubt clear. Lord Rayleigh is there dealing with a case in which the *scale* of the diffraction pattern does not come into consideration, and consequently there is no need to consider the focal length in the expression for the total illumination.

On the Actinic Qualities of Light as Affected by Different Conditions of Atmosphere. By the Rev. J. M. Bacon.

Apart from its relation to photography, this inquiry is of importance to the astronomer as involving considerations with regard to definition, the choice of observing stations, &c.

I have been led step by step to the conclusions at which I have arrived by the following series of tests often and variously repeated:—

Using in all cases uniform samples of sensitised paper or films, and as far as possible eliminating all accidental sources of error, I have, by means of subdued and prolonged exposures, made comparisons between the action of light proceeding from grey or blue sky.

(1) After traversing a length of tube admitting no extraneous light and containing only air at the surrounding temperature.

(2) After traversing the same tube containing various admixtures of smoke and floating mote particles of different kinds.

Here, as was expected, the action of the light was impeded in proportion to the presence of foreign matter.

Similar experiments being repeated with the same media, but diffused light being at the same time freely admitted on all sides, it was found easy so to arrange matters that a slight addition of white smoke rendered the action of the light more rapid, doubtless owing to myriad reflections from the surfaces of its particles

Next, experiments similar to the above were made with air at normal temperature, which was compared with air variously heated. Here currents, condensation, &c., being as far as possible avoided, it was generally found that heated air retarded photographic action until the sensitive surface itself became materially heated, when action might be considerably accelerated.

Yet more marked comparisons were obtained between the effect of ordinary air and the air in which spirit was evaporating. In these cases as the air became charged and its temperature lowered by the evaporation, action was always accelerated in a striking degree.

This is but our familiar experience. In moist weather the distance is blue, clear, and sharp. In warm dry weather distance becomes grey and fades out. In an east wind all things are grey.

Those accustomed to out-door photography are aware how overpoweringly dazzling their sitters will often find the daylight after rain, even though the sky be overcast. Thus in moist weather the atmosphere would seem to be not only more transparent but to convey more diffused light, and it does not suffice as an explanation that floating foreign matter has been cleared away.

In India, at the time of the late eclipse, rain having been absent for a long period, it was found that the action of even the brightest sun on a photographic plate was far less rapid than might have been expected, and became markedly more energetic subsequently when rain clouds overcast the sky. This I exemplified by various photographic views which were projected on the screen at the last meeting of the Society.

At the same meeting I exhibited a series of photographic landscape pictures taken at regular intervals and with uniform exposure while the eclipse was in progress, which pictures went to show that the slow shutting off of the light, commonly noticed before totality, and its rapid return after totality was an actual fact, and not a mere subjective phenomenon. With reference to this Professor Turner has suggested that the explanation may lie in the sudden condensation of moisture occasioned by fall of temperature. The moisture thus condensed had clearly existed previously in the air only in finer subdivision, and its exalted power of transmitting light would seem due to its coalescing in larger particles. It is quite otherwise condensed when the "water dust" produces only the veiling of mist.

Have we some sort of analogy here in the passage of light through grains of, say, broken glass or crystal? The more minute

the grains, *i.e.* the more molecular continuity is destroyed, the more is the light scattered and lost. May it not be so also with regard to moisture particles in suspension? The more subdivided they are, the greater number of limiting surfaces are there to scatter and impair the light.

But I am led to conceive that the intensity of light reaching us from the sky is occasionally influenced by another cause. Arago and others have pointed out, not only the familiar fact that clouds may be luminous, but that certain fogs may be phosphorescent, and they suggest that some such cause may account for certain abnormally light moonless nights; but I would go further and suggest that even clear sky may be phosphorescent also. We are familiar with various bodies often microscopic, in life or death, fitfully phosphorescent. Various noctilucæ render the ocean at times luminous, and light up the actual horizon. Are there no microcosmic organisms in higher strata of the ocean above us which behave similarly?

Again, phosphorescence of such organic matter as may well be in suspension in the atmosphere is thought to be connected with the presence of ozone, which in the atmosphere is a varying quantity. And, again, if it be actually true that it is often "darkest before dawn," then it is conceivable that there may be floating particles of the nature of phosphorescent sulphides or luminous pigments which lose their luminescence as the night proceeds.

A series of experimental photographic records seem to indicate that varying tracts of the night sky are occasionally to some extent self-luminous, but these results need further confirmation on clear moonless nights.

On some Attempts to Counteract by Instrumental Adjustments certain Effects of Refraction in Stellar Photography. By Arthur R. Hinks, B.A.

(*Communicated by Sir R. Ball.*)

Attention has recently been called to the possibility of counteracting to a large extent by instrumental adjustments the effects of refraction in displacing by a continually varying amount the field to be photographed. Dr. Rambaut has shown (*Monthly Notices*, 1896, vol. lvii. p. 50) that the variation with the hour-angle of the component in R.A. of the refraction can be met by suitable changes in the rate of the driving clock. When the polar axis of the telescope is adjusted to the true pole, the requisite change of rate for stars of small north polar distance becomes very large. Mr. Davidson has shown (*Monthly Notices*, 1897, vol. lviii. p. 4) that this difficulty can be overcome

by adjusting the polar axis to the apparent pole as affected by refraction.

Neither Dr. Rambaut nor Mr. Davidson has given numerical details of the variation of the component in declination of the refraction. Yet in practice this component is the more important of the two, while the instrumental means of correcting for it are comparatively inadequate. The device adopted by Dr. Rambaut of introducing a change in clock rate, and consequent continuous trail in R.A., does away almost entirely with the need for small discontinuous hand corrections. But it does not appear that there is any instrumental device in use which will give a corresponding continuous trail in declination, and do for the following in this coordinate what the change in clock rate does for the R.A.'s.

I have been led, therefore, to examine the effect of a displacement of the polar axis of a telescope on the following in declination in the hope of finding a means of perfecting this, even at the expense of the following in R.A. The effect on the latter can then be compensated by modifying the alteration in the rate of the driving clock proposed by Dr. Rambaut.

I. *Effect on the following in declination of a displacement of the instrumental pole.*—Let the elevation of the instrumental above the true pole be e, and let the instrument be set for declination Δ. Let h be the hour-angle of the point to which the telescope is directed at any moment. It is easily seen that the declination δ of this point $=\Delta-e\cos h$, so long as e is small, and δ is not very nearly 90°.

$$\therefore \frac{d\delta}{dh}=e\sin h.$$

The projection on the sky of the intersection of the cross wires of the guiding telescope will therefore be moving in declination at the rate $e \sin h$. The values of this expression in seconds of arc per hour for various values of e and for every hour of hour-angle are given in the following table. The elevation 45″·3 is the adjustment proposed by Mr. Davidson to the apparent pole as affected by refraction in the latitude of Cambridge.

TABLE I.

Rates of Motion in Declination per hour, due to Elevation of the Instrumental Pole.

	Hour-angle West.					
Elevation.	0h.	1h.	2h.	3h.	4h.	5h.
30″	0·0	+2″·0	+3″·9	+5″·6	+6″·8	+7″·6
45·3	0·0	3·1	5·9	8·4	10·3	11·5
60	0·0	4·1	7·9	11·1	13·6	15·2
80	0·0	5·4	10·5	14·8	18·1	20·2
100	0·0	6·8	13·1	18·5	22·7	25·3
120	0·0	8·1	15·7	22·2	27·2	30·4

and so on.

The displacement in declination due to refraction is $\Delta\delta = k \tan z \cos q$, where q is the parallactic angle. And if we put $\tan\theta = \tan c \cos h$, as in Mr. Davidson's paper, this becomes after some reduction

$$\Delta\delta = k \cot (\delta + \theta)$$

$$\therefore \frac{d}{dh} \Delta\delta = k \tan c \sin h \operatorname{cosec}^2 \overline{\delta + \theta} \cos^2 \theta$$

The values of this expression are given in the following table:—

TABLE II.

Rates of Motion in Declination per hour due to Refraction.

Decl.	Hour-angles. 0h.	1h.	2h.	3h.	4h.	5h.	6h.
°	"	"	"	"	"	"	"
0	0·0	+5·5	+13·2	+27·9	...	...	...
+10	0·0	3·8	8·5	16·5	+33·3	...	...
+20	0·0	2·8	6·3	11·4	20·6	+40·7	...
+30	0·0	2·3	5·1	8·8	14·7	25·2	+47·4
+40	0·0	2·1	4·4	7·4	11·6	18·0	28·7
+50	0·0	2·0	4·2	6·7	10·0	14·3	20·2
+60	0·0	2·0	4·1	6·5	9·1	12·3	16·2
+70	0·0	2·2	4·3	6·6	8·9	11·3	13·7
+80	0·0	2·5	4·9	7·2	9·3	11·0	12·2

We have now from Table I. the motion in declination of the projection on the sky of the cross wires, due to the elevation of the instrumental pole; and from Table II. we have the motion in declination of the guiding star, due to refraction. If these two quantities can be made equal the following in declination will be perfect.

It is convenient to plot the quantities in these tables as curves. If a tracing of one set is then laid over the other, it immediately appears, as is indeed plain from a comparison of the tables, that for polar stars, and for stars as far south as 20° N. decl. at small hour-angles, the effects of Mr. Davidson's proposed adjustment to the apparent pole are as valuable with respect to the following in declination as he has himself shown them to be in R.A. The outstanding drift in declination of the guiding star, which remains to be corrected by hand, is in general less than a second of arc per hour. The compensation fails, however, for equatorial stars and for stars of medium north declination at considerable hour-angles. In these cases some further adjustment is desirable.

Suppose for the moment that the instrumental pole could be adjusted with ease to any desired polar distance and hour-angle. It is clear that the effect of the adjustment to any hour-angle H would be to alter the rates given in Table I. for a

star of hour-angle h to the corresponding rates for hour-angle $h-\mathrm{H}$. To examine the effect of such an adjustment it is sufficient to slide the tracing of the curves from Table I. over the curves from Table II. by an amount corresponding to the value of H.

In this way it is possible to select for a star of given declination, which is to be photographed at a given hour-angle, a suitable displacement of the instrumental pole, such that over a considerable space the portions of the curves showing the variations in declination due to refraction and displacement of the instrumental pole respectively fit one another almost exactly; for half an hour or more the following in declination will then be almost perfect.

The following table shows for various declinations and hour-angles suitable displacements of the instrumental pole approximately determined by this method.

Table III.

Values of e *and* H, *Displacements of the Instrumental Pole.*

Decl.	Hour-angle. 0^{h}.	1^{h}.	2^{h}.	3^{h}.	4^{h}.	5^{h}.
$0°$	80″	100″	160″	320″	...	...
	0^{h}	$0^{h}\cdot2$	$0^{h}\cdot7$	$1^{h}\cdot7$	...	...
+10	60″	60″	80″	160″	400″	...
	0^{h}	$0^{h}\cdot1$	$0^{h}\cdot3$	$1^{h}\cdot4$	$2^{h}\cdot9$	...
+20	45″	45″	70″	100″	180″	...
	0^{h}	$0^{h}\cdot1$	$0^{h}\cdot6$	$1^{h}\cdot3$	$2^{h}\cdot2$	...
+30	40″	40″	45″	80″	120″	240″
	0^{h}	0^{h}	$0^{h}\cdot4$	$1^{h}\cdot3$	$2^{h}\cdot1$	$3^{h}\cdot4$
+40	30″	30″	40″	60″	90″	140″
	0^{h}	0^{h}	$0^{h}\cdot5$	$1^{h}\cdot2$	$2^{h}\cdot0$	$3^{h}\cdot0$
+50	30″	30″	40″	50″	70″	100″
	0^{h}	0^{h}	$0^{h}\cdot4$	$1^{h}\cdot0$	$1^{h}\cdot8$	$2^{h}\cdot8$

Unfortunately the interest of this table is almost entirely theoretical. It is not possible in existing forms of instruments to alter the adjustment of the polar axis to suit each particular exposure, and there would be very considerable if not quite hopeless difficulties in the way of mounting an instrument with this facility of adjustment. Moreover, if the instrumental is much displaced from the true pole a very serious rotation of the field is produced, and the following would not be perfect except in the centre of the field. This point is considered in detail later.

For general photographic work, at all sorts of declinations,

and, in the case of parallax work, at considerable distances from the meridian, a complete adjustment appears to be impossible. But for work on a zone of small breadth, such as astrographic chart work, where the photographs can all be taken near the meridian, the case is different. In the latitudes of English observatories the adjustment to the apparent pole answers fairly well, except for stars of large N.P.D.; but the adjustments given in the first column of Table III. will, I believe, be found even more satisfactory.

In low latitudes adjustment to the apparent pole is altogether wrong, except for work in the immediate neighbourhood of the pole. As an illustration of this, I give a table showing for the various observatories participating in the work of the astrographic chart, the elevation of the instrumental pole best suited to each case. The last column gives for comparison the elevation to the apparent pole.

	Latitude.	Zones (Decl.)	Suggested Elevation of Pole.	Elevation to Apparent Pole.
	° ′	° °	″	″
Greenwich	+51 29	+90 to +65	35	46
Rome	+41 54	+64 „ +55	30	66
Catania	+37 30	+54 „ +47	30	76
Helsingfors	+60 9	+46 „ +40	30	33
Potsdam	+52 23	+39 „ +32	30	45
Oxford	+51 46	+31 „ +25	35	46
Paris	+48 50	+24 „ +18	40	51
Bordeaux	+44 50	+17 „ +11	40	58
Toulouse	+43 37	+10 „ + 5	50	61
Algiers	+36 48	+ 4 „ − 2	45	78
San Fernando	+36 28	− 3 „ − 9	55	79
Tacubaya	+19 24	−10 „ −16	30	166
Santiago	−33 27	−17 „ −23	30	92
La Plata	−34 35	−24 „ −31	35	85
Rio de Janeiro	−22 54	−32 „ −40	20	138
Cape of Good Hope	−33 56	−41 „ −51	30	87
Sydney	−33 52	−52 „ −64	35	87
Melbourne	−37 50	−65 „ −90	50	75

The calculations were made for the middle of each zone.

II. *Corrections to the rate of the driving clock.*—Any elevation of the instrumental pole will necessitate corrections to Dr. Rambaut's clock rates, similar to those proposed by Mr. Davidson. The expression for the correction is

$$+ \epsilon \cos h \tan \delta.$$

The following table gives the value of this correction when $e = 100''$. The corrections for the elevation actually chosen can thence be easily calculated.

TABLE IV.

Corrections to be applied to the daily Clock Rates proposed by Dr. Rambaut for an Elevation of the Instrumental Pole of 100″.

Decl.	Hour-angle. 0h.	1h.	2h.	3h.	4h.
0°	+0s·0	+0s·0	+0s·0	+0s·0	+0s·0
+10	7·4	7·1	6·4	5·2	3·7
+20	15·2	14·7	13·2	10·8	7·6
+30	24·2	23·4	20·9	17·1	12·1
+40	35·2	33·9	30·4	24·8	17·6
+50	49·9	48·2	43·2	35·3	25·0
+60	72·6	70·1	62·8	51·3	36·3

This table is independent of the latitude, and can be used for any observatory. Dr. Rambaut's table is, of course, strictly applicable only to the latitude of Dunsink.

III. *Rotation of the field due to displacement of the polar axis.*—Let us now neglect for the time any effects of refraction and suppose that the stars are describing uniformly circles about the true pole. Let the instrumental pole P′ be at a distance e from the true pole P in hour-angle H.

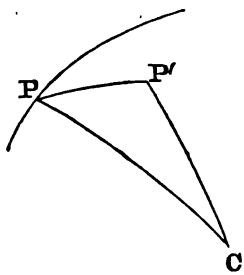


FIG. 1.

Let C be the projection of the centre of a plate in hour-angle h and instrumental polar distance p. Let the angle PCP′ be θ. The projection of CP′ on the plate will be what we may call the instrumental north and south line, while the projection of CP will be the true north and south line. And the angle θ varies with h. There will therefore be a rotation of the field during exposure measured by the value of $\frac{d\theta}{dh}$.

We have

$$\sin (h-H) \sin e = \sin p \sin \theta.$$

Differentiating

$$\frac{d\theta}{dh} = \frac{\sin e \cos (h-H)}{\sin p \cos \theta}$$

and except for regions close to the pole we may put

$$\cos \theta = \text{unity, and } \frac{d\theta}{dh} = \frac{\sin e \cos (h-H)}{\sin p}$$

The values of this expression, in units of circular measure per hour, for the case $e = 100''$ are given in the following table:—

TABLE V.

Rotation per hour of the Field when the Instrumental Pole is displaced 100" *from the True Pole.*

		$h-H$				
		0^h.	1^h.	2^h.	3^h.	4^h.
Decl.	0°	·000127	·000123	·000110	·000090	·000063
	+10	129	124	112	91	64
	+20	135	130	117	96	68
	+30	147	142	127	104	73
	+40	166	160	144	117	83
	+50	198	191	171	140	99
	+60	·000254	·000245	·000220	·000180	·000127

The trail of a star whose coordinates on the plate are $(\xi\,\eta)$ will then be $-\eta\frac{d\theta}{dh}$ and $+\xi\frac{d\theta}{dh}$ in the two coordinates.

For example, if $\xi=\eta=\tan 1°$, and the declination is $+60°$, the corresponding values of $-\eta\frac{d\theta}{dh}$ or $+\xi\frac{d\theta}{dh}$ are

$$\mp 0''\cdot 91 \qquad \mp 0''\cdot 88 \qquad \mp 0''\cdot 79 \qquad \mp 0''\cdot 65 \qquad \mp 0''\cdot 46$$

The effect, therefore, on stars near the edge of the field is by no means inconsiderable; and displacements of the instrumental pole as large as some of those in Table III. are clearly out of the question except for short exposures or a very small field.

IV. *Rotation and distortion of the field, due to variation of the refraction with the time.*—Up to this point we have considered the effects of refraction upon a central guiding star and the consequent errors in the following. We have now to examine the effects upon the surrounding field.

The most appropriate refraction formulæ for use in this

examination are those derived by Professor Turner for rectangular coordinates (*Monthly Notices*, 1894, vol. liv. p. 19).

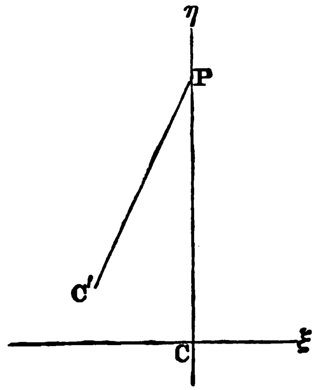


FIG. 2.

Let $C\xi$, $C\eta$ be the axes of coordinates of a plate, the projection P on the plate of the pole lying in $C\eta$. Let (X, Y) be the coordinates of the projection of the zenith; β_0, the constant of refraction.

Then if $(\xi\eta)$ be the coordinates of the projection of a star's true place those of the apparent place as affected by refraction are $(\xi+\Delta\xi,\ \eta+\Delta\eta)$, where

$$\Delta\xi = \beta_0\,[X-(1+X^2)\,\xi - XY\eta]$$
$$\Delta\eta = \beta_0\,[Y - XY\xi - (1+Y^2)\,\eta]$$

neglecting small quantities of the second order.

If now the clock is rated to sidereal time, and the instrument is adjusted to the true pole, the path of the projection of C on the sky will be that of a star unaffected by refraction. Owing to the variation of the refraction with the hour-angle all the stars will trail upon the plate, and the expressions for the rate of trail in the two coordinates are

$$\frac{d}{dh}\,\Delta\xi = \beta_0\left[\frac{dX}{dh} - 2X\frac{dX}{dh}\xi - \left(X\frac{dY}{dh} + Y\frac{dX}{dh}\right)\eta\right]$$
$$\frac{d}{dh}\,\Delta\eta = \beta_0\left[\frac{dY}{dh} - \left(X\frac{dY}{dh} + Y\frac{dX}{dh}\right)\xi - 2Y\frac{dY}{dh}\eta\right]$$

These expressions may be conveniently divided into two :—

The first terms of each, $\beta_0\frac{dX}{dh}$ and $\beta_0\frac{dY}{dh}$, are the trail of a star whose true position unaffected by refraction would be at C.

This is our guiding star, and these terms indicate a translation of the field as a whole.

The remaining terms of the expressions

$$-\beta_0\left[2X\frac{dX}{dh}\xi+\left(X\frac{dY}{dh}+Y\frac{dX}{dh}\right)\eta\right]$$
$$-\beta_0\left[\left(X\frac{dY}{dh}+Y\frac{dX}{dh}\right)\xi+2Y\frac{dY}{dh}\eta\right]$$

involve ξ and η, and indicate a distortion of the field.

The guiding star is displaced by refraction from C to C′, and the position of C′ is constantly varying. The telescope must be made to follow it, and the north and south line on the plate is always C′P. The angle between this line and CP, which we may call the original axis of η, will therefore be continually changing, and a rotation of the field results.

We have then to evaluate two separate effects, a rotation and a distortion of the field.

A. *Rotation of the field.*—If the angle CPC′$=\phi$, and the N.P.D. of C is P, we have

$$\tan\phi=\frac{\beta_0 X}{\tan P}$$

very nearly, except for regions close to the pole. And ϕ is small.

$$\therefore \frac{d\phi}{dh}=\frac{\beta_0}{\tan P}\frac{dX}{dh} \text{ nearly.}$$

If c is the colatitude, h the hour-angle of the centre of the plate, the coordinates of the projection of the zenith on the plate are

$$X=\frac{\tan h\sin q}{\cos(P-q)}$$
$$Y=\tan(P-q)$$

where $\tan q=\tan c\cos h$.

Then

$$Y=\frac{\tan P-\tan c\cos h}{1+\tan P\tan c\cos h}$$

and

$$\frac{dY}{dh}=\frac{\tan c\sin h\sec^2 P}{(1+\tan P\tan q)^2}$$

Also

$$\tan h=\frac{X\operatorname{cosec} P}{1-Y\cot P}$$

$$\therefore X=\sin P\tan h-\cos P\tan h\,.\,Y$$

and

$$\frac{dX}{dh}=(\sin P-Y\cos P)\sec^2 h-\cos P\tan h\frac{dY}{dh}$$

From these expressions the values of $\frac{dX}{dh}, \frac{dY}{dh}$ were calculated for every hour of hour-angle from 0^h to 4^h, and for every 10° of declination from 0° to +50°.

Substituting then the values of $\frac{dX}{dh}$ in the equation $\frac{d\phi}{dh} = \frac{\beta_0}{\tan P}\frac{dX}{dh}$, the quantities of the following table were obtained:

TABLE VI.

Values of $\beta_0 \frac{dX}{dh} / \tan P$ *expressed in Circular Measure per hour.*

Decl.	Hour-angle. 0^h.	1^h.	2^h.	3^h.	4^h.
0°	·0000000	·0000000	·0000000	·0000000	·0000000
+10	108	114	133	176	280
+20	196	203	227	276	379
+30	284	292	313	356	443
+40	390	397	414	447	502
+50	·0000544	·0000544	·0000554	·0000571	·0000592

The trail of a star $(\xi\eta)$ due to this rotation will then be $+\eta\frac{d\phi}{dh}$ and $-\xi\frac{d\phi}{dh}$ in the two coordinates.

The rotation is in the opposite sense to that due to the elevation of the pole, and will therefore tend to counteract it. For declinations above 40°, with a suitable elevation of the pole, the compensation is fairly good, and the resultant rotation of the field is negligible. But near the equator the rotation due to the refraction is small, and that due to the elevation of the pole is able to produce its full effect.

B. *Distortion of the field.*—If we put

$$-\beta_0 2X\frac{dX}{dh} = A$$
$$-\beta_0\left(X\frac{dY}{dh}+Y\frac{dX}{dh}\right) = B$$
$$-\beta_0 2Y\frac{dY}{dh} = C$$

the trails of a star $(\xi\eta)$ tending to distort the field are at the rates $A\xi+B\eta$, $B\xi+C\eta$ in the two coordinates.

The values of A, B, and C are given in the following table to three significant figures, and are expressed in units of circular measure per hour :—

TABLE VII.

Values of A, B, and C.

Decl.		Hour-angles. 0^h.	1^h.	2^h.	3^h.	4^h.
0°	A	–·0000000	–·0000426	–·000114	–·000297	–·00103
	B	·0000955	·000114	·000184	·000407	·00134
	C	·0000000	·0000709	·000190	·000494	·00171
+10	A	·0000000	·0000284	·0000700	·000154	·000384
	B	·0000560	·0000645	·0000976	·000186	·000458
	C	·0000000	·0000336	·0000858	·000199	·000532
+20	A	·0000000	·0000214	·0000497	·0000971	·000198
	B	·0000339	·0000391	·0000576	·000102	·000214
	C	·0000000	·0000178	·0000443	·0000970	·000228
+30	A	·0000000	·0000176	·0000388	·0000691	·000123
	B	·0000200	·0000236	·0000354	·0000614	·000169
	C	·0000000	·0000097	·0000241	·0000520	·000115
+40	A	·0000000	·0000156	·0000330	·0000549	·0000854
	B	·0000100	·0000127	·0000215	·0000393	·0000731
	C	·0000000	·0000047	·0000124	·0000280	·0000620
+50	A	·0000000	·0000147	·0000301	·0000469	·0000656
	B	·0000018	·0000041	·0000115	·0000255	·0000488
	C	–·0000000	–·0000011	–·0000043	–·0000129	–·0000329

From this table the rate of trail in each coordinate at any point of the plate may be easily calculated.

For in seconds of arc per hour

$$\frac{d}{dh}\Delta\xi = \frac{1}{\sin 1''}(A\xi + B\eta)$$

$$\frac{d}{dh}\Delta\eta = \frac{1}{\sin 1''}(B\xi + C\eta)$$

where (ξ, η) are the coordinates of any point on the plate expressed in circular measure.

Consider, as an example, the case of a plate 2° square, with centre 10° N. and 3^h from the meridian. If $\xi = \eta = \tan 1°$

$$\frac{A\xi}{\sin 1''} = -0''\!\cdot\!55 \qquad \frac{B\xi}{\sin 1''} = -0''\!\cdot\!67 \qquad \frac{C\eta}{\sin 1''} = -0''\!\cdot\!72$$

and

at the point		the rate of trail per hour is in ξ	in η
$\xi = \eta = \tan 1°$		$-1''22$	$-1''\!\cdot\!39$
$\xi = \tan 1°$	$\eta = 0$	$-0''\!\cdot\!55$	$-0''\!\cdot\!67$
$\xi = \tan 1°$	$\eta = -\tan 1°$	$+0''\!\cdot\!12$	$+0''\!\cdot\!05$
$\xi = 0$	$\eta = \tan 1°$	$-0''\!\cdot\!67$	$-0''\!\cdot\!72$

A star at the first point will then be trailing inwards at the rate of nearly 2″ per hour; and during a long exposure the star discs in this and in the opposite corner of the plate will be very seriously distorted.

In this way was calculated the following table :—

TABLE VIII.

Values of $\frac{d}{dh}\Delta\xi$, $\frac{d}{dh}\Delta\eta$, *being Rates of Trail per hour in each Coordinate for a Star at the corner* $\xi = \eta = \tan 1^\circ$ *of the plate, for various Declinations and Hour-angles.*

Decl.	Hour angle.				
	0^h.	1^h.	2^h.	3^h.	4^h.
0°	″ −0·35	″ −0·56	″ −1·07	″ −2·54	″ − 8·53
	0·35	0·67	1·34	3·25	10·98
+10	0·20	0·33	0·60	1·22	3·03
	0·20	0·35	0·66	1·39	3·56
+20	0·12	0·22	0·39	0·72	1·48
	0·12	0·20	0·37	0·72	1·59
+30	0·07	0·14	0·27	0·47	0·87
	0·07	0·11	0·22	0·41	0·84
+40	0·04	0·11	0·20	0·34	0·57
	0·04	0·07	0·12	0·24	0·48
+50	0·01	0·06	0·15	0·26	0·42
	0·01	0·01	0·06	0·14	0·30

These results appear to me to throw some doubt on Dr. Rambaut's belief that photographs suitable for accurate measurement can be obtained six hours or more from the meridian (*Monthly Notices*, 1896, vol. lvii. p. 52). I have not considered the case of hour-angles greater than four hours, because I have shown elsewhere (*Monthly Notices*, 1898, vol. lviii. p. 442) that, with reasonable luck in the matter of weather, it should never be necessary to take photographs for stellar parallax much more than four hours from the meridian. The importance of making every effort to work at the smallest possible hour-angle is evident from the table.

V. *General conclusions.*—Stellar photographs generally fall into one of two classes :—

A. Short exposures, less than 10^m.

B. Long exposures, an hour and upwards.

The astrographic catalogue plates and plates for stellar parallax belong to class A.

It is extremely desirable that as little hand correction as possible should be given to these photographs, destined for the most accurate measurement. It will therefore be advisable to elevate

the pole and adjust the clock-rates in order to ensure good following. For general work at varying declinations and hour-angles an elevation of about 60″ will probably be found best. For work in narrow zones, and near the meridian, other values of the elevation are found. Except near the equator the rotations of the field tend to counteract one another, and near the meridian the distortion is not very serious.

Astrographic chart plates, and plates intended for the parallax of clusters and nebulæ, fall into class B. For them it is a delicate matter to balance the respective merits or demerits of good following, absence of hand correction, rotation or distortion of the field. Near the equator and on the meridian it is best to adjust to the true pole, and sacrifice easy following to freedom from rotation, since distortion is fairly small. Far from the meridian distortion becomes so large that rotation is comparatively a minor ill. But here a small elevation of the pole has little effect on the following.

In high declinations the rotations compensate one another, and the distortions are small. It is here that the advantages of elevation of the pole are most fully realised, and there seems to be no reason why long exposure photographs should not be susceptible of very accurate measurement.

It is, however, useless to attempt to frame any general rules. Each case must be decided after a weighing of conflicting interests. But there seemed to be a want of numerical data on which to form a judgment. The tables contained in this paper were therefore calculated as a preliminary to the work which is to be shortly undertaken with the new photographic equatorial of the Cambridge Observatory; and they are now published in the hope that they may be found of more extended use.

Cambridge Observatory:
1898 *June* 4.

A Diagram showing the Conditions under which Observations for the Determination of Stellar Parallax are to be made. By Arthur R. Hinks, B.A.

(*Communicated by Sir R. S. Ball.*)

The diagram which is here described was constructed to facilitate the arrangement of the stellar parallax work to which the Director proposes to devote the new photographic equatorial of the Cambridge Observatory.

It shows for a star of any R.A. between the limits of declination 0° and +60°

a. The two days of the year on which the parallactic displacement of the star is a maximum.

b. The mean time on those days at which it is most favourably situated for observation.

c. The hour-angle and zenith distance at which it is then to be observed.

The diagram thus serves as a guide in the choice of seasons for work on any star; and also as a guide to the order in which the photographs of all the stars in a night's working list should be taken, to avoid as far as possible large zenith distances.

I publish it now in the hope that the idea of such a diagram and the methods of its construction may be useful to others engaged in stellar parallax work.

The displacement of a star due to annual parallax is greatest at the two moments when the star is 90° from the Sun.

If then H and D are the hour-angle and declination of the Sun, h and δ the hour-angle and declination of a star, a condition for maximum parallactic displacement is

$$\text{Sin D} \sin \delta + \cos \text{D} \cos \delta \cos (\text{H} - h) = 0 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

I have assumed that it is possible to begin photographing when the Sun is 10° below the horizon. The corresponding hour-angle of the Sun, H, is given by the equation

$$\text{Cos } 100^\circ = \cos c \sin \text{D} + \sin c \cos \text{D} \cos \text{H} \quad . \quad . \quad . \quad . \quad (2)$$

where c is the colatitude of the observatory.

From equation (2) we find H the apparent time, and thence the mean time, at which it is possible to begin photographing on any day in the year. If in (1) we substitute this value of H and the corresponding value of D, we have a relation connecting the declinations and hour-angles at the time of beginning work of all the stars which are then at maximum parallactic displacement.

The construction of the diagram, therefore, proceeded as follows:—

The hour-angles H of the Sun when it reaches the zenith distance 100° were calculated from equation (2) for every fifteenth day of the year.

These values of H and the corresponding values of D were then substituted in equation (1), and the values of h obtained for every 10° of declination δ, from the equator to +60°. These values of h were plotted on millimetre paper, with dates as abscissæ and hour-angles as ordinates; and the curves drawn through the corresponding points of each set form the declination curves of the diagram.

Again, from the value of H we find the sidereal time at which the Sun reaches the zenith distance 100° on any day; and then we can lay down a series of points representing the hour-angles at this instant for stars of each hour of R.A. This was done for each fifteenth day; and the curves drawn through corresponding points of each series are the R.A. curves of the diagram.

Along the bottom were laid down for various dates the mean

times corresponding to the calculated apparent times H at which the Sun reaches the zenith distance 100°.

In a precisely similar manner the curves were laid down which show the conditions under which the star is to be observed in the morning, when it is at the opposite apse of its parallactic ellipse.

Finally, at the right-hand side of the diagram, the curves were drawn which give for every 10° of declination the zenith distances corresponding to the hour-angles.

The use of the diagram is best illustrated by examples.

Suppose we require to observe for parallax a star in R.A. 10^h; Decl. +40°. The intersection of the corresponding curves gives May 7 as the date for the evening observation. The scale of mean times at the bottom shows that the Sun reaches the zenith distance 100° at about $8^h\ 45^m$ M.T. on that day. This is the time at which we can begin photographing. The scale of ordinates shows that the hour-angle of the star is then 29° W.; and the curves on the right give 23° as the corresponding zenith distance.

On the same evening we can see that stars whose positions are R.A. 9^h Decl. 0°, and R.A. 11^h Decl. +60° might be in the working list. At $8^h\ 45^m$ their respective zenith distances are 63° and 10°. We should therefore start at the earliest possible moment on the equatorial star. When that was done—in half an hour, say—we could get the star 40° N. at about 27° Z.D.; and after another half-hour the star 60° N. at 13° Z.D.

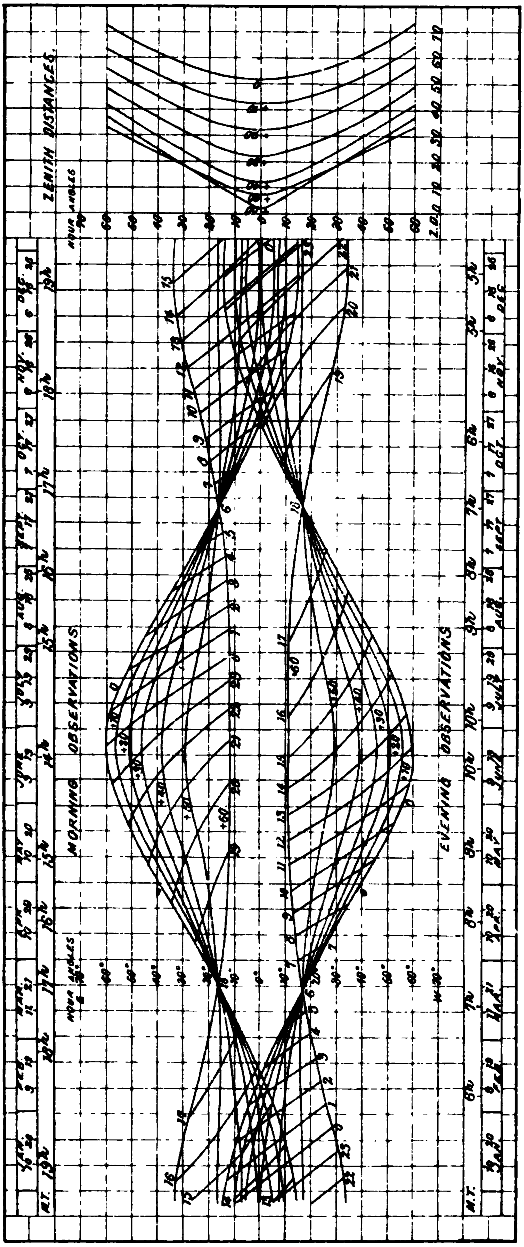
A simple inspection of the diagram gives then the conditions of hour-angle and zenith distance at the earliest times in the evening and the latest times in the morning at which the stars in the night's working list can be photographed. And in general these limiting times will be the best times for the work, since the zenith distances are then the smallest possible consistent with the conditions under which the work is to be done.

In some cases, however, the diagram shows that this is not true. For example, stars within 30° of the equator which are to be observed in the mornings in midwinter have passed the meridian when the Sun attains the zenith distance 100°; and it will be better to take them a little earlier, when they are on the meridian.

Granted fine weather, and the possibility of starting work very early in the evening and continuing it very late in the morning, it will be practicable, as the diagram shows, to avoid having to work at any hour-angle much exceeding three hours, except in the middle of summer, when the hour-angles for equatorial stars become almost prohibitively large. An extreme case is that of a star on the equator in R.A. 12^h, which in the case of the evening observation could not be photographed before it had reached the zenith distance 73°.

The diagram as published reproduces only too faithfully one or two irregularities, due to unskilful drawing of the original. All the declination curves should of course intersect in two

Time Chart for Parallax Observations, Cambridge Observatory.



points corresponding to the two equinoxes, which correspondence is in the drawing not quite exact. The accuracy of the drawing is, however, amply good enough for the purpose for which it was made.

Cambridge Observatory:
1898 *May* 28.

Revised Catalogue of the Stars of the IV. Type.
By the Rev. T. E. Espin, M.A.

The arrangement of the present catalogue is identical with that of the first catalogue of the Stars of the IV. Type, published in the *Monthly Notices*, vol. xlix. p. 364. The letter H has been used to signify the stars detected at the Harvard Observatory either visually, or by the photo-telescopes at Harvard and Arequipa. Professor Pickering has kindly sent me a complete list of these, containing some that have not hitherto been published. Also some notes on stars in the first catalogue, which, together with my own observations, have caused the removal of several stars from the list, and their being assigned to Type III. One star, No. 191, in the present catalogue, of which Professor Pickering writes, "Omit, not confirmed by the photographs," I have still ventured to retain, as although the star is not above 11·5 mag. I have no doubt as to the correctness of the earlier Harvard observations. I have observed it on several occasions, and although faint the type seemed certain. The stars in Column II. marked Es. and followed by a number, are stars not in the B.D. The other abbreviations in Column VI. are as follows: Se., Secchi; Du., Dunér; D'A., D'Arrest; P., Pechüle; V., Vogel.

The following is a general summary of the catalogue, the first column giving the limiting magnitude, the second the number of stars north of the equator, the third the number of stars south, and the last the totals, the variable stars being entered according to their maximum magnitude:—

Mag.	N.	S.	Total.
to 6·0	3	4	7
6·1 „ 7·0	12	11	23
7·1 „ 8·0	19	20	39
8·1 „ 9·0	51	25	76
Below 9·0	69	11	80
Mag. not given	1	11	12
Total	155	82	237

Excluding variables our knowledge of the number of stars of Type IV. is probably complete for the N. heavens as far as 8·9, and for the southern heavens as far as 8·5. The catalogue

contains twenty-eight variables to which letters have been assigned: twenty-two are north and six south. It would appear that almost all the stars of Type IV. are subject to fluctuations in brightness, though the red colour makes it not easy to decide when the variation is small.

No.	B.D. &c.	R.A. (1900). h m	Decl. (1900). ° ′	Mag.	Authority.
1	+49°,41	0 12·3	+49 44	9·0	H.
2	+43°,53	14·6	+44 9	8·2	Sa.
3	Es. 832	16·8	+58 36	9·9	Es.
4	+53°,66	19·1	+53 44	9·3	H.
5	+34°,56	22·2	+35 2	8·1	Du.
6	+63°,56	25·5	+63 19	9·3	Es.
7	W Cassiopeiæ	49·0	+58 1	Var.	"
8	+62°,211	1 2·6	+62 27	9·5	"
9	+25°,205	10·6	+25 15	7·0	D'A.
10	R Sculptoris	22·4	−33 3	Var.	H.
11	+59°,274	26·8	+60 8	9·0	Es.
12	Es. 230	27·1	+57 14	9·2	"
13	Es. 1076	37·7	+60 7	9·8	"
14	Es. 1181	37·8	+61 7	9·6	"
15	+53°,379	38·7	+53 28	9·4	H.
16	X Cassiopeiæ	49·8	+58 46	Var.	Es.
17	Es. 1084	2 3·4	+63 9	9·7	"
18	+11°,305	9·6	+11 47	8·9	H.
19	+51°,575	19·8	+51 37	9·0	Es.
20	−10°,513	30·2	−9 53	8·0	H.
21	+38°,525	32·1	+38 44	9·4	Es.
22	+58°,501	32·3	+59 10	9·5	"
23	V Persei	43·3	+56 34	Var.	H.
24	+57°,647	43·6	+57 26	8·9	Du.
25	+57°,702	3 3·7	+57 31	7·9	H.
26	+47°,783	6·7	+47 27	9·0	Es.
27	+43°,726	20·9	+43 50	8·9	"
28	U Cameli	33·2	+62 19	Var.	Du.
29	+51°,762	34·1	+51 11	8·9	Es.
30	C.Z.C. 3^{h}·1404	46·7	−43 50	8·5	H.
31	Es. 1111	51·3	+60 33	9·2	Es.
32	+61°,667	57·2	+61 31	7·5	"
33	+50°,920	4 3·9	+51 5	9·5	"
34	+50°,961	9·0	+50 22	9·5	"

No.	B.D. &c.	R.A. (1900). h m	Decl. (1900). ° ′	Mag.	Authority.
35	+48°,1083	4 13·6	+48 56	9·5	Es.
36	T Cameli	30·4	+65 57	Var.	"
37	Es. 985	32·6	+41 23	9·2	"
38	+42°,1046	39·6	+42 29	9·5	"
39	+67°,350	40·8	+68 0	7·0	Se.
40	+34°,911	42·6	+34 49	8·8	Es.
41	C.G.C. 5429	43·8	−36 23	7·6	H.
42	+28°,707	45·2	+28 21	8·1	Se.
43	+38°,955	45·8	+38 20	8·8	Es.
44	+22°,770	47·8	+22 37	9·2	"
45	R Leporis	55·0	−14 57	Var.	D'A.
46	+50°,1112	55·6	+50 29	8·9	Es.
47	+0°,939	5 0·2	+ 1 2	6·0	Se.
48	+38°,1038	2·5	+38 54	9·5	Es.
49	+45°,1053	2·8	+46 2	9·5	"
50	−5°,174	4·9	− 5 39	8·7	Du.
51	+35°,1046	12·5	+35 41	8·9	Es.
52	+32°,957	15·3	+32 25	9·3	"
53	S Aurigæ	20·5	+34 4	Var.	Du.
54	+7°,929	27·8	+ 7 4	8·2	Es.
55	S Cameli	30·2	+68 45	Var.	"
56	C.G.C. 6519	31·7	−25 48	7·5	H.
57	+24°,898	32·4	+24 57	9·5	Es.
58	+17°,979	35·5	+17 29	8·0	H.
59	+24°,943	39·1	+24 23	8·5	Du.
60	+20°,1083	39·7	+20 39	7·7	"
61		40·4	−46 30	7½	P.
62	+44°,1288	41·2	+44 48	9·2	Es.
63	+30°,1014	41·7	+30 35	8·5	"
64	+26°,1117	6 4·7	+26 2	7·4	D'A.
65	+27°,1024	7·3	+27 12	9·0	Se.
66	+29°,1177	13·2	+29 31	9·5	Es.
67	V Aurigæ	16·3	+47 43	Var.	"
68	+3°,1214	17·1	+ 3 28	9·0	"
69	+25°,1250	17·8	+25 4	9·5	"
70	+14°,1283	19·8	+14 47	6·5	Se.
71	Es. 243	20·3	+19 8	Var. ?	Es.
72	+38°,1539	29·7	+38 32	6·3	Se.
73	Es. 1142	33·3	+22 42	9·4	Es.

No.	B.D. &c.	R.A. (1900). h m	Decl (1900). ° ′	Mag.	Authority.
74	+31°,1388	6 35·7	+31 33	8·1	Es.
75	+3°,1381	39·4	+ 3 25	9·3	H.
76	Es. 63	42·4	+ 0 47	9·6	Es.
77	−6°,1786	47·5	− 7 0	9·1	"
78	−4°,1708	48·2	− 4 27	9·0	"
79	C.G.C. 8670	51·3	−42 14	6·7	H.
80	+6°,1462	53·0	+ 6 18	8·0	Es.
81	Es. 1144	55·3	+68 19	10	"
82	−3°,1685	56·0	− 3 7	7·7	"
83	−7°,1742	7 2·1	− 7 24	8·3	"
84	−11°,1805	3·4	−11 46	7·6	Se.
85	+14°,1594	6·6	+14 53	9·0	Es.
86	+25°,1643	14·9	+25 10	9·2	"
87	−3°,1873	18·1	− 4 2	9·2	H.
88	−3°,1885	19·9	− 4 2	8·7	Es.
89	−2°,2101	20·2	− 2 57	9·0	"
90	+24°,1686	25·8	+24 43	8·2	"
91	+2°,1715	31·3	+ 2 18	9·3	"
92	U Canis Min.	35·9	+ 8 37	Var.	V.
93	+5°,1797	43·4	+ 5 40	9·0	Es.
94	C.G.C. 10488	53·5	−49 43	8	P.
95	−12°,2289	57·5	−12 44	10	H.
96	−38°,4049	8 1·7	−38 29	—	"
97	−22°,2160	3·1	−22 38	8·6	"
98	+3°,1958	14·9	+ 3 5	8·3	Es.
99	−17°,2442	15·2	−17 57	9·1	H.
100	C.G.C. 11890	42·4	−29 21	7·9	"
101	+17°,1973	49·7	+17 37	6·5	D'A.
102	T Cancri	51·0	+20 14	Var.	Es.
103	+14°,2048	9 8·3	+14 37	8·8	H.
104		13·5	−65 49	—	"
105	−1°,2312	45·9	− 1 33	8·9	"
106	−22°,2739	46·4	−22 33	6·6	Se.
107		51·3	−41 7	7·5	P.
108	C.G.C. 13699	57·9	−59 49	7¾	"
109	C.G.C. 13396	10 7·5	−34 50	7½	"
110	C.G.C. 14440	30·8	−39 3	5·9	H.
111	U Hydræ	32·6	−12 52	Var.	Se.
112	+68°,617	38·1	+67 56	6·2	Du.

No.	B.D. &c.	R.A. (1900). h m	Decl. (1900). ° ′	Mag.	Authority.
113		10 42·5	−65 5	—	H.
114	V Hydræ	46·8	−20 43	Var.	Se.
115	+69°,644	56·5	+69 47	8·9	H.
116	C.Z.C. $11^{\rm h}$·129	11 2·9	−54 35	9	"
117	C.Z.C. $11^{\rm h}$·742	11·2	−57 23	9	"
118	−13°,3407	30·7	−14 2	8·5	"
119	C.G.C. 15946	35·0	−72 0	8·5	"
120		55·3	−54 33	—	"
121		12 9·4	−50 58	—	"
122		19·3	−48 51	—	"
123	+1°,2694	20·1	+1 19	8·1	Se.
124	−37°,7905	24·0	−37 42	8·8	H.
125	+46°,1817	40·4	+45 59	5·5	Se.
126	+66°,780	52·5	+66 32	7·3	"
127	+38°,2389	54·7	+38 21	8·6	H.
128	C.Z.C. $13^{\rm h}$·717	13 13·4	−73 55	$8\frac{1}{2}$	"
129	C.G.C. 18157	15·5	−63 42	8	"
130	C.Z.C. $13^{\rm h}$·1490	26·4	−53 19	9·6	"
131	C.G.C. 18947	51·6	−55 51	8	"
132	C.G.C. 19254	14 7·4	−53 28	7·5	"
133	C.G.C. 19416	15·7	−49 24	$8\frac{1}{2}$	"
134	C.G.C. 19745	29·5	−42 56	8·5	"
135		52·2	−53 0	—	"
136	C.G.C. 20554	15 4·8	−69 42	6·2	"
137	C.G.C. 20937	21·9	−24 49	7·6	"
138	V Coronæ	45·9	+39 52	Var.	Du.
139	RR Herculis	16 1·5	+50 46	Var.	Es.
140		21·1	−43 26	—	H.
141	V Ophiuchi	21·2	−12 12	Var.	Du.
142		39·8	−67 36	—	H.
143	C.G.C. 23005	54·3	−54 55	$8\frac{1}{2}$	"
144		17 11·6	−45 52	—	"
145	−19°,4644	23·9	−19 23	7·8	Du.
146	C.G.C. 23935	34·7	−57 40	7·0	H.
147	−18°,4634	39·1	−18 37	8·5	Du.
148	C.Z.C. $17^{\rm h}$ 2657	40·8	−35 40	8·0	H.
149	T Draconis	54·9	+58 14	Var.	Es.
150	−39°,12196	58·2	−39 20	9·0	H.
151	+9°,3576	18 4·0	+9 26	9·4	"

No.	B.D. &c.	R.A. (1900). h m	Decl. (1900). ° ′	Mag.	Authority.
152	−19°,4907	18 7·8	−19 16	9·5	Es.
153	Holden 150	7·9	−19 7	—	„
154	−13°,4918	12·7	−13 29	9·2	„
155	−15°,4923	13·6	−15 39	9·0	H.
156	−38°,12843	23·4	−38 29	9·5	„
157	+4°,3779	26·4	+ 4 19	9·3	Es.
158	T Lyræ	28·9	+36 55	Var.	Se.
159	−7°,4633	31·6	− 7 41	9·0	Es.
160	+32°,3160	33·6	+33 1	9·3	„
161	C.Z.C. 18h·1935	35·2	−51 51	9	H.
162	+36°,3243	39·4	+36 52	7·5	Se.
163	−8°,4726	44·9	− 8 1	7·1	Du.
164	+0°,4046	52·4	+ 0 19	9·2	Es.
165	+14°,3729	54·0	+14 14	9·0	Du.
166	+10°,3764	57·5	+10 6	9·5	Es.
167	V Aquilæ	59·1	− 5 50	Var.	V.
168	C.G.C. 26129	59·7	−38 17	8·3	H.
169	−16°,5272	19 13·4	−16 6	6·8	„
170	+10°,3857	13·8	+10 20	9·5	Es.
171	U Lyræ	16·6	+37 41	Var.	„
172	+76°,734	25·1	+76 22	6·5	Se.
173	+45°,2906	25·8	+45 50	8·6	Es.
174	−16°,5360	28·6	−16 35	7·2	Se.
175	+32°,3522	37·1	+32 23	8·0	Du.
176	−18°,5480	40·6	−18 24	9·1	H.
177	Es. 1021	42·9	+15 48	9·5	Es.
178	+85°,332	43·8	+85 9	9·2	H.
179	+24°,3902	46·3	+24 41	9·2	Es.
180	Es. 415	46·7	+14 45	9·8	„
181	+43°,3425	54·0	+43 59	8·2	Du.
182	−7°,5141	55·7	− 7 39	9·8	H.
183	+9°,4369	56·3	+ 9 14	8·7	„
184	Es. 181	57·1	+30 33	9·5	Es.
185	+20°,4390	58·9	+20 48	9·4	„
186	+40°,4001	20 0·9	+40 9	9·5	„
187		5·1	+35 31	—	H.
188	+41°,3632	6·3	+41 12	Var.	Es.
189	+47°,3031	6·4	+47 33	Var.	Du.
190	RY Cygni	6·6	+35 38	Var.	H.

No.	B.D. &c.	R.A. (1900). h m	Decl. (1900). ° ′	Mag.	Authority.
191	Pickering No. 38	20 7·3	+35 48	(11)	H.
192	RS Cygni	9·8	+38 28	Var.	Du.
193	−21°,5672	11·2	−21 37	Var.	Se.
194	Es. 1170	11·8	+36 47	11	Es.
195	Es. 900	12·4	+37 34	10	,,
196	Es. 417	13·2	+49 38	Var.	,,
197	Es. 902	13·3	+36 36	11·5	,,
198	+37°,3876	14·8	+37 5	9·5	,,
199	U Cygni	16·5	+47 34	Var.	Se.
200	+35°,4077	17·4	+35 18	9·5	Es.
201	+37°,3903	17·9	+37 13	9·4	,,
202	RW Cygni	25·2	+39 39	Var.	,,
203	−12°,5755	26·2	−12 13	9·2	H.
204	+40°,4210	27·4	+40 11	9·4	Es.
205	+68°,1140	36·1	+68 12	8·8	,,
206	V Cygni	38·1	+47 47	Var.	V.
207	+45°,3271	43·5	+45 41	Var.	Es.
208	+32°,3954	45·2	+32 51	9·4	,,
209	Es. 1172	21 6·5	+32 57	9·1	,,
210	C.G.C. 29232	13·6	−45 27	6·0	H.
211	Es. 923	14·4	+51 49	9·5	Es.
212	C.G.C. 29252	15·2	−70 10	6·8	H.
213	+41°,4114	18·6	+41 58	9·5	Du.
214	+61°,2134	23·3	+62 8	8·8	Es.
215	+49°,3535	25·8	+49 53	9·4	,,
216	+47°,3429	26·1	+48 7	9·5	,,
217	S Cephei	36·5	+78 10	Var.	Du.
218		36·6	−65 30	—	H.
219	+34°,4500	37·8	+35 3	6·2	D'A.
220	RV Cygni	39·1	+37 34	Var.	Se.
221	+53°,2693	40·7	+53 15	9·2	Es.
222	Es. 931	43·0	+52 5	9·5	,,
223	+52°,3036	43·6	+52 13	9·3	,,
224	+49°,3673	51·5	+50 1	9·1	Du.
225	C.G.C. 30526	22 16·6	−46 27	6·7	H.
226	Es. 1046	24·8	+64 23	10	Es.
227	+60°,2432	40·4	+61 12	8·9	,,
228	+54°,2863	43·6	+54 38	9·5	,,
229	+45°,4121	57·2	+45 21	9·5	,,

No.	B.D. &c.	R.A. (1900).	Decl. (1900).	Mag.	Authority.
		h m	° ′		
230	Es. 1048	23 6·0	+60 43	9·0	Es.
231	−21°,6376	6·3	−21 32	9	H.
232	+48°,4051	22·2	+48 58	9·3	Es.
233	+2°,4709	41·3	+2 56	6·2	Se.
234	+5°,5223	44·0	+5 50	8·7	H.
235	+60°,2634	48·0	+60 27	9·0	Es.
236	+59°,2810	56·2	+59 48	7·8	Du.
237	+42°,4827	59·5	+43 0	8·4	Es.

Further Researches on the Orbit of γ Lupi = h 4786.
By T. J. J. See, A.M., Ph.D. (Berlin).

In the *Monthly Notices* for 1897 November I have indicated the general nature of the orbit of γ *Lupi*. At the time that paper was prepared, it did not seem probable that a material improvement of the result announced could be expected for some twenty years; but a few observations made by Captain Jacob at a particularly opportune epoch, near the middle of the century and unknown to me at the time of my first investigation, have made possible a revision which defines the motion of this remarkable star with singular precision. We are thus enabled to determine a set of elements which are very satisfactory. Considering the small number of observations available, it must be conceded that this result is one of the happiest yet afforded by the history of double star astronomy. The excellence of the orbit derived from only a few observations is due to their advantageous distribution, which gives each measure a particularly decisive import. The singular and almost unique character of the orbit also renders its determination comparatively easy. We find that the system of γ *Lupi* is situated like that of 42 *Comæ Berenices*, and that all the motion takes place in a right line at position angles 93°·5—273°·5. An investigation of the areas described shows that the major axis of this system does not depart sensibly from the line of sight; and hence the determination of the elements is somewhat easier than in the case of 42 *Comæ Berenices*, where λ differs sensibily from 90°.

As nearly all the observations of γ *Lupi* were given in my former paper, I content myself here with adding those since unexpectedly discovered, and a few which Mr. Boothroyd and I have recently taken at Flagstaff.

t	θ_0	ρ_0	Remarks.
1853·125	274°·6	1″·14	1n Jacob. Discs in contact.
1853·130	272·4	0·98	1n Jacob. Preceding star certainly the least, but the difference is less than half a magnitude.
1856·171	275·4	0·75	3–2n Jacob. Magnitudes 4–4.
1877·411	Not divided		1n Melbourne Obs., 8-inch refractor.
·419	" "		1n " "
·422	Plainly elongated		1n " "
1878·679	Not divided		1n " "
1898·302	93·9	0·40	See. Clearly separated with black line between components.
·302	92·7	0·46	
·302	92·0	0·35	See. Excellent measures.
·302	93·9	0·35	
1898·302	93·4	0·46	Boothroyd.

The Melbourne observations were kindly communicated by Mr. Innes, of the Royal Observatory, Cape of Good Hope.

It is singular that Captain Jacob should have been able to measure this close object with a 5-inch telescope, and the result speaks well for his skill as an observer. It is needless to say that his observations now possess an interest scarcely inferior to those of Herschel himself.

As the south declination of this object is about 41°, our recent observations were made at an altitude of only about 12° or 13°; yet under a singularly steady atmosphere the stars were well shown, and most of the time distinctly divided. The measures are therefore entitled to the highest confidence.

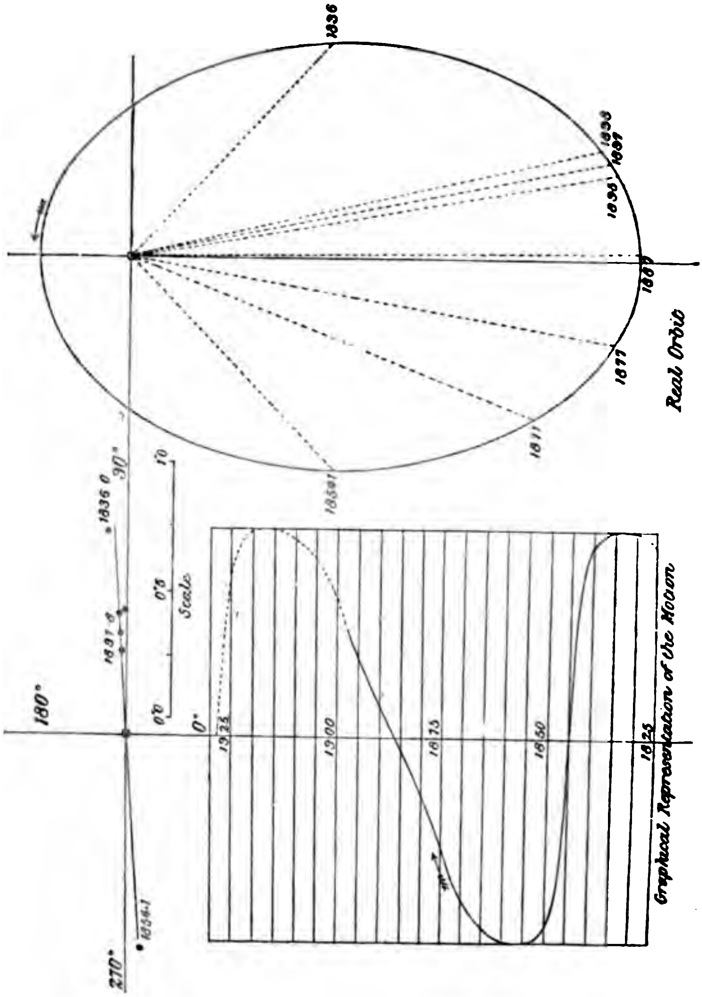
The following are the elements of γ *Lupi* = *h* 4786 :

$P = 83{\cdot}0$ years	$\Omega = 93^\circ{\cdot}5$
$T = 1845{\cdot}0$	$i = 90^\circ{\cdot}\pm$
$e = 0{\cdot}70$	$\lambda = 90^\circ{\cdot}\pm$
$a = 1''{\cdot}10$	$n = \pm 4^\circ{\cdot}3374$

Apparent orbit, a right line in $93^\circ{\cdot}5 - 273^\circ{\cdot}5$, $1''{\cdot}56$ in length.

In the accompanying table these elements are compared with the best means I could form from all the known observations of this star. As the elements are approximate, and the motion rather slow, I have taken the epochs merely to the nearest tenth year.

The figure shows the real and apparent orbits, and gives a graphical representation of the motion. The components are now steadily widening out, and ought soon to be visible to other southern observers.



Real Orbit

Graphical Representation of the Motion

Orbit of γ *Lupi* = *h* 4786.

The period of γ *Lupi* remains uncertain to the extent of possibly five years, but a longer correction to the above value seems altogether improbable.

Comparison of computed with observed places.

t	θ_o	θ_c	ρ_o	ρ_c	$\theta_o-\theta_c$	$\rho_o-\rho_c$	n	Observers.	Remarks.
	°	°	″	″	°	″			
1836·0	95·3	93·5	0·78	0·78	+1·8	0·00	16–9	Herschel	
1854·1	274·1	273·5	0·83	0·78	+0·6	0·05	5–3	Jacob	
1871·5		273·5		0·58			1	Russell	Not divided.
1877·5	270·±	273·5		0·31	−3·5		1	Russell	Smaller end goes first.
1887·5		93·5		0·03			1	Pollock	Single in 11½ in.
1895·6		93·5		0·32			3	Sellors	Single
1897·1	92·4	93·5	0·34	0·36	−1·1	−0·02	2	See	
1897·1	90·4	93·5	0·47	0·36	−3·1	+0·11	1	Cogshall	
1898·3	93·1	93·5	0·39	0·40	−0·4	−0·01	2	See	
1898·3	93·4	93·5	0·46	0·40	−0·1	+0·06	1	Boothroyd	

The eccentricity of the orbit is quite high, and is comparatively well determined by the great inequality of the motion at the two apses. The value here found will probably not require a correction larger than $\pm$0·05.

In closing I may perhaps observe that this remarkable system and 42 *Comæ* appear to differ from *Algol* variables chiefly in the equal luminosity of both components and the greater periods required for the revolution of their attendants.

Lowell Observatory, Flagstaff, Arizona:
1898 *May* 20.

Note on the Level Errors of the Cape Transit Circle.
By W. H. Finlay, M.A.

In vol. i. Part V. of the *Annals of the Cape Observatory* I discussed the variations of the adjustments of the transit circle from the time of its erection, 1856, up to 1882. The most interesting of these variations were those in level, which were shown to have a well-marked annual period, and which also, there was some reason to believe, were subject to a period of about 18 or 19 years.

As the results of 15 additional years are now available it may be of interest to put on record the behaviour of the level during that time.

In 1894 the error of azimuth had become inconveniently large. On May 16–17 both Ys were moved from their founda-

tion plates, and the instrument was adjusted in azimuth. Corrections have been applied to the observations taken after this date to allow for the sudden change of level caused by this operation, and similarly in all cases where there was a change arising from mechanical interference with the instrument.

The following table gives the level errors from 1885 to 1897, formed in the same way and reduced to the same system as those given in the *Annals* for 1856–1884.*

Values of Level Error.

		1885.	1885.	1887.	1888.	1889.	1890.	1891.
		″	″	″	″	″	″	″
Jan.	1	−3·88	−3·24	−3·01	−3·34	−2·52	−2·39	−1·96
	15	−3·90	−3·13	−2·93	−3·36	−2·58	−2·43	−2·09
Feb.	1	−3·70	−3·05	−2·98	−3·29	−2·66	−2·49	−2·07
	15	Object-glass being re-polished	−3·01	−3·08	−3·26	−2·71	−2·43	−2·14
Mar.	1		−3·00	−3·14	−3·29	−2·74	−2·43	−2·16
	15		−3·07	−3·18	−3·16	−2·86	−2·48	−2·06
Apr.	1		−3·10	−3·44	−3·29	−3·02	−2·44	−2·10
	15		−3·14	−3·54	−3·37	−3·10	−2·52	−2·10
May	1		−3·21	−3·73	−3·45	−3·02	−2·63	−2·18
	15		−3·42	−3·63	−3·45	−3·11	−2·70	−2·26
June	1		−3·47	−3·77	−3·54	−3·10	−2·74	−2·35
	15		−3·45	−3·72	−3·54	−3·17	−2·72	−2·39
July	1		−3·46	−3·80	−3·66	−3·19	−2·72	−2·53
	15		−3·51	−3·76	−3·63	−3·17	−2·79	−2·44
Aug.	1		−3·51	−3·78	−3·32	−3·19	−2·80	−2·44
	15	−4·08	−3·47	−3·78	−3·22	−3·12	−2·79	−2·47
Sept.	1	−3·94	−3·44	−3·64	−3·18	−2·94	−2·57	−2·36
	15	−3·89	−3·40	−3·48	−2·97	−2·84	−2·38	−2·35
Oct.	1	−3·76	−3·29	−3·39	−2·80	−2·76	−2·36	−2·31
	15	−3·79	−3·30	−3·38	−2·73	−2·74	−2·31	−2·12
Nov.	1	−3·63	−3·26	−3·32	−2·65	−2·51	−2·10	−2·10
	15	−3·52	−3·15	−3·20	−2·50	−2·53	−2·12	−1·91
Dec.	1	−3·42	−3·12	−3·14	−2·52	−2·46	−2·03	−1·86
	15	−3·36	−3·03	−3·27	−2·48	−2·43	−1·97	−1·84
Means		[−3·70]	−3·26	−3·42	−3·16	−2·85	−2·47	−2·19

* It must be understood that the level errors given here are not the ones used in the ordinary reduction of observations. By occasional adjustment the level error in use has been kept small, but for my purpose corrections have been applied to allow for these adjustments, so as to exhibit the errors as they would have been without alteration from the beginning.

		1892.	1893.	1894.	1895.	1896.	1897.	1898.	Means.
		"	"	"	"	"	"	"	"
Jan.	1	−1·80	−1·54	−1·49	−1·37	−1·61	−1·73	−2·22	−2·16
	15	−1·76	−1·54	−1·47	−1·40	−1·53	−1·75	−2·18	−2·16
Feb.	1	−1·76	−1·50	−1·40	−1·41	−1·49	−1·77	−2·33	−2·15
	15	−1·75	−1·41	−1·48	−1·35	−1·43	−1·75	−2·28	−2·15
Mar.	1	−1·75	−1·55	−1·47	−1·35	−1·30	−1·80	−2·29	−2·16
	15	−1·76	−1·48	−1·55	−1·31	−1·50	−1·95	−2·35	−2·19
Apr.	1	−1·79	−1·45	−1·69	−1·49	−1·62	−2·04	−2·52	−2·29
	15	−1·88	−1·60	−1·56	−1·61	−1·58	−2·16	−2·71	−2·35
May	1	−1·98	−1·71	−1·56	−1·64	−1·77	−2·19	−2·67	−2·43
	15	−2·10	−1·65	−1·58	−1·76	−1·77	−2·30	−2·77	−2·48
June	1	−2·13	−1·80	−1·99	−1·88	−1·80	−2·39	...	−2·58
	15	−2·21	−1·74	−1·98	−2·01	−1·79	−2·45	...	−2·60
July	1	−2·19	−1·73	−1·99	−1·90	−1·89	−2·46	...	−2·63
	15	−2·28	−1·78	−2·03	−1·99	−1·89	−2·47	...	−2·65
Aug.	1	−2·19	−1·77	−2·12	−1·95	−1·96	−2·51	...	−2·63
	15	−2·09	−1·85	−2·09	−1·91	−1·97	−2·45	...	−2·60
Sept.	1	−1·90	−1·78	−1·91	−1·99	−1·89	−2·50	...	−2·51
	15	−1·90	−1·74	−1·91	−2·01	−1·94	−2·59	...	−2·46
Oct.	1	−1·83	−1·75	−1·81	−1·81	−1·91	−2·57	...	−2·39
	15	−1·99	−1·64	−1·76	−1·79	−1·87	−2·47	...	−2·34
Nov.	1	−1·94	−1·68	−1·69	−1·84	−1·83	−2·45	...	−2·29
	15	−1·92	−1·51	−1·67	−1·71	−1·82	−2·44	...	−2·21
Dec.	1	−1·78	−1·41	−1·49	−1·72	−1·86	−2·39	...	−2·14
	15	−1·77	−1·44	−1·45	−1·61	−1·78	−2·29	...	−2·11
Means		−1·93	−1·61	−1·71	−1·74	−1·73	−2·24		

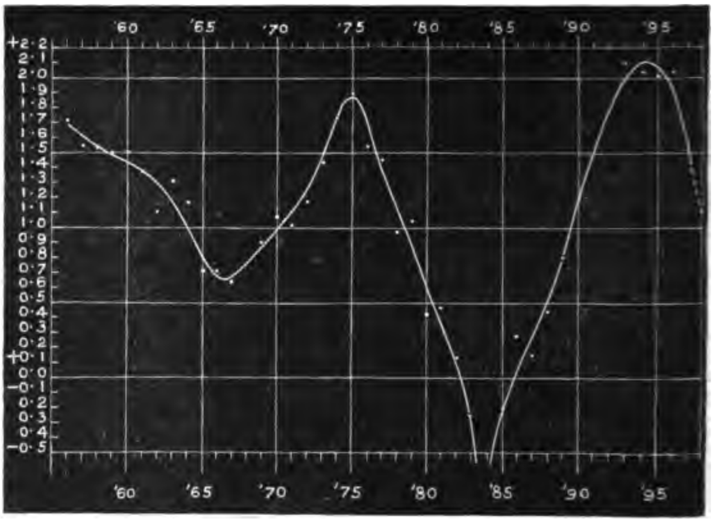
It is at once obvious from an inspection of the yearly means that for some years after erection there was a rapid sinking of the western pier, which has gradually diminished till at the present time it is almost insensible; so that the assumption (made in my previous paper) of a uniform fall will not fit the later observations.

We might allow for this sinking in various ways, but I shall content myself with assuming that it proceeded in a geometrical progression of which the first term is 0·28 and ratio 0·93.

Correcting the yearly means, then, from the expression $4\{1-(0·93)^n\}$, where n denotes the number of years from 1856, we obtain the following figures for the variation of level:—

Year.	Level Error.	Year.	Level Error.	Year.	Level Error.	Year.	Level Error.
1856	+1″·71	1867	+0″·66	1878	+0″·98	1889	+0″·79
1857	1·55	1868	0·77	1879	1·05	1890	1·19
1858	1·54	1869	0·91	1880	0·42	1891	1·49
1859	1·50	1870	1·08	1881	0·47	1892	1·77
1860	1·51	1871	1·01	1882	+0·13	1893	2·10
1861	1·37	1872	1·18	1883	−0·24	1894	2·04
1862	1·11	1873	1·44	1884	−0·97	1895	2·02
1863	1·31	1874	1·73	1885	−0·19	1896	2·04
1864	1·18	1875	1·90	1886	+0·29	1897	+1·55
1865	0·73	1876	1·54	1887	0·16		
1866	+0·72	1877	+1·46	1888	+0·44		

The results for the present year, so far as they go, show that the level error will be at least 0·4 smaller than in 1897.



The above values for the level error are represented in the figure, and it is evident that my conjecture of a period of about 19 years is fully borne out.

Right Ascensions and Declinations of Eight Stars of the Constellation Aquarius; also their probable Proper Motions. By C. J. Merfield.

Introduction.—The following coordinates in right ascension and declination, together with the most probable values of the proper motions, are the result of some inquiry necessary to establish good positions for certain stars of the constellation *Aquarius*, and used by Mr. J. Tebbutt as comparison stars when observing the minor planet (194) *Procne** during the year 1897. As these positions may be useful for other purposes, the writer presents the results to the Society.

The author has to acknowledge especially the kindness shown to him by Mr. H. C. Russell, C.M.G., for granting permission to consult the various star catalogues contained in the Library of the Sydney Observatory. Also his thanks are due to Mr. R. C. Walker, Principal Librarian for the Sydney Public Library, and to Mr. J. Tebbutt, of Windsor, for their kindly assistance.

The methods of Dr. H. S. Davis have been followed, and a *résumé* is given in the following paragraphs :—

Precession.—The year 1875 is the epoch of reduction selected. For this purpose the formulæ of Professor Hill and the constants of Peters and Struve have been adopted. These have been taken from the *Report on the Declinations of Stars employed in Latitude Work with the Zenith Telescope.*

Introducing these constants into the formulæ we have the following :—

$$\frac{d\alpha}{dt} = 3^{s}{\cdot}07225 + [0{\cdot}126115] \sin\alpha \tan\delta + \mu$$

$$\frac{d\delta}{dt} = [1{\cdot}302206] \cos\alpha + \mu'$$

$$\frac{d\mu}{dt} = [5{\cdot}9877-10]\, \mu \cos\alpha \tan\delta + [4{\cdot}8116-10]\, \mu' \sin\alpha \sec^2\delta + [4{\cdot}987-10]\, \mu\mu' \tan\delta$$

$$\frac{d^2\alpha}{dt^2} = [4{\cdot}6338\underset{n}{0}-10] \left(\frac{d\alpha}{dt} - \mu\right) + [5{\cdot}98778-10] \left(\frac{d\alpha}{dt} + \mu\right) \cos\alpha \tan\delta + [4{\cdot}81169-10] \left(\frac{d\delta}{dt} + \mu'\right) \sin\alpha \sec^2\delta + [4{\cdot}9866-10]\, \mu\mu' \tan\delta + 0^{s}{\cdot}000\ 032\ 210$$

$$\frac{d^2\delta}{dt^2} = [4{\cdot}6338\underset{n}{0}-10] \left(\frac{d\delta}{dt} - \mu'\right) + [7{\cdot}1638\underset{n}{7}-10] \left(\frac{d\alpha}{dt} + \mu\right) \sin\alpha + [6{\cdot}736\underset{n}{7}-10]\, \mu^2 \sin 2\delta$$

$$\frac{d^3\delta}{dt^3} = [2{\cdot}0987-10] \left(\frac{d\alpha}{dt} + \frac{\mu}{2}\right) \sin\alpha + [7{\cdot}1638-10] \left(\frac{d^2\alpha}{dt^2} + \frac{d\mu}{dt}\right) + [3{\cdot}025\underset{n}{5}-10] \left(\frac{d\alpha}{dt} + \mu\right) \left(\frac{d\alpha}{dt}\right) \cos$$

* See *Astronomical Journal*, vol. xviii. No. 420.

in which α, δ, μ, μ' represent respectively the right ascension, declination, and the annual proper motions which have been assumed for the adopted epoch. The numbers in brackets are logarithms.

For convenience the following notation* has been adopted; that is, let

$$J = \frac{d\alpha}{dt} \qquad\qquad K = \frac{d^2\alpha}{dt^2} \times 10^2$$

$$L = \frac{d\delta}{dt} \qquad M = \frac{d^2\delta}{dt^2} \times 10^2 \qquad N = \times \frac{d^3\delta}{dt^3} \times \frac{1}{6} \times 10^6$$

Also let T be the epoch of any catalogue, and denote the right ascension and declination given in the catalogue by α_T, δ_T.

Then

$$\alpha_{1875} = \alpha_T + J(1875-T) + K\frac{-(1875-T)^2}{200}$$

$$\delta_{1875} = \delta_T + L(1875-T) + M\frac{-(1875-T)^2}{200} + N\left(\frac{1875-T}{100}\right)^3$$

Proper Motions.—The right ascensions or declinations given in the catalogues that have been reduced to the epoch of the catalogue with a proper motion μ_a or μ_δ have been corrected by the addition of the quantity

$$(T-t)\ (\mu-\mu_a)$$

or

$$(T-t)\ (\mu'-\mu_\delta)$$

in which T denotes the epoch of the catalogue, and t the date of observation of the star. In several cases the value of t could not be found from the catalogues examined, nor could information be obtained from the libraries at disposal; the value of t has therefore been taken equal to T under such circumstances.

Systematic Corrections.—To reduce the resulting positions for 1875 to the system of the *Fundamental-Catalog für die Zonen-Beobachtungen der Astronomischen Gesellschaft*, the results of Professor Auwers have been employed, and interpolated from the tables published in the *Astronomische Nachrichten*, No. 3195–96 and 3413–14. In some cases the catalogues used have not been investigated by Auwers, so that a correction of 0·00 has been used.

* The notation of Dr. Davis has been adopted throughout, with some few alterations, to meet the requirements of this inquiry. See "Variation of Latitude of New York City."

Weights.—To each catalogue a weight has been assigned, according to the number of observations, and based approximately upon the relative magnitude of their respective probable errors. In cases where the number of observations was not directly or otherwise obtainable, then the assumption is made that at least one observation has been taken.

Probable Errors.—The probable errors of the several deductions have been computed from the squares of the residuals by the usual formulæ. Dr. H. S. Davis has pointed out that these formulæ put the probable errors of each star on an independent basis. On the same line and in the last column of the table of results there will be found a coefficient to multiply the probable errors given, so that they will be comparable and applicable for use in combination with the probable errors of observation of other quantities. This coefficient depends on the number of catalogues used.

Formulæ for Adjustment.—The data of each catalogue give an equation of condition of the usual form

$$\sqrt{p}\{a_0 - [B + \Delta\mu_0 (t - T_0)] = R\}$$

in which

p = the weight;
a_0 = the seconds of desired mean right ascension for the epoch T_0;
B = the seconds of observed right ascension after the systematic correction has been applied;
$\Delta\mu_0$ = the correction to be *subtracted* from the assumed value of μ;
T_0 = the mean date by weight of all the observations;
R = the residual after substituting the derived values of the unknowns.

A similar equation for the declination is obtained by replacing a_0 by δ_0 and accenting B, $\Delta\mu_0$, and R.

The solution of these equations of condition is not so laborious if the method of Professor Safford be adopted; thus by assuming T_0 as the initial date we have

$$T_0 = \frac{[pt]}{[p]} \text{ and } a_0 = \frac{[pB]}{[p]}$$

Substituting these values in the equations of condition, and letting $a_0 - B = E$, $t - T_0 = C$, and $pC = D$, then

$$\Delta\mu_0 = \frac{[DE]}{[CD]}$$

Results. Right Ascensions. Epoch 1875.

Mr. Tebbutt's Number.	Name.	Date of Observation.	Number of Observations.	Number of Catalogues.	α_{1875}			J	K	Proper Motion μ.	Probable error of α at the epoch 1875.	Probable error of μ at the date of observation.	η
		T_0	[n]	m	h	m	s	s	s	s	s	s	
11	Radcliffe 6025	1877·67	14	4	22	20	0·746	+3·1518	−0·0071	0·0000	±0·002	±0·0001	8·50
15	Radcliffe 6026	1859·60	47	12	22	20	3·216	+3·1909	−0·0093	+0·0021	±0·006	±0·0002	1·44
7	Radcliffe 6038	1877·08	12	5	22	23	56·967	+3·1242	−0·0057	+0·0052	±0·014	±0·0005	0·92
14	Radcliffe 6040	1862·78	548	40	22	24	1·845	+3·1810	−0·0088	−0·0026	±0·002	±0·0001	1·27
10	Radcliffe 6041	1869·18	20	8	22	24	44·855	+3·1404	−0·0065	+0·0076	±0·014	±0·0007	0·73
	Radcliffe 6042	1874·98	15	8	22	24	50·719	+3·1057	−0·0047	−0·0055	±0·014	±0·0006	0·73
5	Radcliffe 6073	1862·33	27	8	22	34	19·851	+3·1081	−0·0046	−0·0042	±0·017	±0·0005	0·63
6	Piazzi xxii 191	1861·98	19	8	22	35	38·343	+3·1070	−0·0045	0·0000	±0·011	±0·0004	1·06

Declinations. Epoch 1875.

Mr. Tebbutt's Number.	Name.		Date of Observation. T_0	Number of Observations. [n]	Number of Catalogues. m	δ_{1875}	L′	M	N	Proper Motion μ'	Probable error of δ at the epoch 1875	Probable error of μ' at the date of observation.	η'
11	Radcliffe	6025	1877·67	15	4	− 8° 0′ 42″·317	+18″·1758	+0″·1864	−0″·1693	−0″·0465	±0″·070	±0″·0045	2·51
15	Radcliffe	6026	1857·49	43	13	−11 51 47·084	+18·1773	+0·1890	−0·1757	+0·0022	±0·099	±0·0025	1·09
7	Radcliffe	6038	1876·71	9	5	− 5 27 30·348	+18·3187	+0·1775	−0·1660	+0·0352	±0·228	±0·0089	0·78
14	Radcliffe	6040	1864·41	367	39	−11 19 1·199	+18·3216	+0·1806	−0·1747	−0·0169	±0·032	±0·0014	1·09
10	Radcliffe	6041	1869·17	22	8	− 7 11 32·250	+18·3470	+0·1770	−0·1686	−0·1258	±0·155	±0·0085	0·73
3	Radcliffe	6042	1875·63	14	7	− 3 33 3·830	+18·3504	+0·1748	−0·1631	−0·0284	±0·197	±0·0079	0·67
5	Radcliffe	6073	1863·88	27	8	− 4 12 15·540	+18·6694	+0·1575	−0·1657	−0·0319	±0·103	±0·0032	1·25
6	Piazzi xxii	191	1863·46	13	6	− 4 7 34·237	+18·7108	+0·1550	−0·1658	−0·0059	±0·075	±0·0029	2·24

NOTE.

Stars No. 10, 13, 14, have been used by Professor Frisby. See *Astronomical Journal*, No. 415. Radcliffe numbers refer to the 1890 Catalogue.

$$\alpha_T = \alpha_{1875} + (J' + \mu)\ (T - 1875) + K\ \frac{(T-1875)^2}{200}$$

$$\delta_T = \delta_{1875} + (L' + \mu')\ (T - 1875) + M\ \frac{(T-1875)^2}{200} + N\left(\frac{T-1875}{100}\right)^3$$

Occultations of Ceres and of Venus, observed at the Cambridge Observatory.

(*Communicated by Professor Sir R. S. Ball, Director of the Observatory.*)

Occultation of Ceres, 1897 *November* 13.

Reappearance. First seen G.M.T. $11^h\ 31^m\ 29^s{\cdot}2$.

The observation was made with the Northumberland equatorial, aperture $11\frac{3}{4}$ in. The seeing was fair. The planet was first seen as a very unsteady and ill-defined patch of light, which grew steadily brighter, and was estimated as of full brightness 5^s after its first appearance.

Occultation of Venus, 1898 *May* 22.

Disappearance. Second contact G.M.T. $6^h\ 51^m\ 47^s{\cdot}0$.

Reappearance. Third contact G.M.T. $7^h\ 30^m\ 50^s{\cdot}1$.

The observations were made with the Northumberland equatorial. Seeing was very unsteady. First contact was missed. Bisection at disappearance was noted at $6^h\ 51^m\ 27^s$, which is uncertain by one or two seconds owing to the unsteadiness of the image. The planet lingered for several seconds as an irregular line of light, and then went out sharply, the observation of the time of second contact being noted as good. The observation of third contact was noted, "not more than half a second late, if so much." The seeing was so bad that no attempt was made to estimate the time of bisection at reappearance. The time of fourth contact was noted as $7^h\ 31^m\ 30^s$, which is uncertain by several seconds.

The observations were made by Mr. A. R. Hinks.

Cambridge Observatory:
1898 *May* 25.

Observations of Comet b 1898 (Perrine) made at the Royal Observatory, Greenwich.

(Communicated by the Astronomer Royal.)

The observations were made with the Sheepshanks equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

Greenwich Mean Solar Time.	Observer.	☄ — ✱ R.A.	Corr. for Refraction.	Log Factor of Parallax.	☄ — ✱ N.P.D.	Corr. for Refraction.	Log Factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1898. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
May 18 12 8 9	A. C.	−0 15·30	0·00	9·4644	−0 27·0	−0·1	0·9018	3	2 7 46·47	34 40 23·9	*a*

Notes.

The observations are corrected for refraction but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

The initials A. C. are those of Mr. Crommelin.

Comparison Star.

	Star's Name.	Assumed R.A. 1898·0.	Assumed N.P.D. 1898·0.	Authority.
		h m s	° ′ ″	
a	B.D. + 55°, No. 552	2 8 1·31	34 40 59·9	Cambridge (U.S.) and Helsingfors-Gotha Astr. Gesell. Catalogues.

Royal Observatory, Greenwich:
1898 *June* 10.

Observations of Phenomena of Jupiter's Satellites with the 8-*inch Equatorial of the Windsor Observatory, New South Wales, in the Year* 1897. By John Tebbutt.

Day of Obs.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation.	Mean Time of *N. Almanac.*
1897.					h m s	h m s
Feb. 22	I.	Tr. Egr.	Bisection	70	23 57 2	24 0 0
23	I.	„	Ext. contact	„	0 2 7	
Mar. 8	III.	Tr. Ingr.	Ext. contact	„	23 35 20	
8	III.	„	Bisection	„	23 39 14	23 40 0
8	III.	„	Int. contact	„	23 43 9	
25	I.	Ecl. R.	First seen	„	23 11 59	23 12 11
25	I.	„	Full brightness	„	23 15 0	
27	II.	Occ. D.	First contact	„	22 47 32	
27	II.	„	Bisection	„	22 51 7	22 53 0
27	II.	„	Last seen	„	22 53 51	
30	IV.	Occ. R.	Bisection	„	22 54 24	22 56 0
30	IV.	„	Last contact	„	23 1 23	
Apr. 1	I.	Occ. D.	First contact	„	21 55 24	
1	I.	„	Bisection	„	21 58 59	22 0 0
1	I.	„	Last seen	„	22 1 18	
5	II.	Tr. Egr.	Int. contact	„	22 8 36	
5	II.	„	Bisection	„	22 12 20	22 12 0
5	II.	„	Ext. contact	„	22 15 45	
9	I.	„	Int. contact	„	23 23 6	
9	I.	„	Bisection	„	23 26 11	23 27 0
9	I.	„	Ext. contact	„	23 29 25	
16	IV.	Ecl. D.	Began to fade	„	20 7 25	
16	IV.	„	Last seen	„	20 15 46	20 15 27
16	I.	Tr. Ingr.	Ext. contact	„	22 54 57	
16	I.	„	Bisection	„	22 56 51	22 56 0
16	I.	„	Int. contact	„	22 59 6	
17	I.	Occ. D.	First contact	„	19 57 50	
17	I.	„	Bisection	„	20 1 0	20 4 0
17	I.	„	Last seen	„	20 3 59	
17	I.	Ecl. R.	First seen	„	23 24 45	23 24 58
17	I.	„	Full brightness	„	23 28 35	

Day of Obs.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation.	Mean Time of *N. Almanac*.
1897.					h m s	h m s
Apr. 26	I.	Ecl. R.	First seen	70	19 48 23	19 48 34
26	I.	„	Full brightness	„	19 50 54	
28	II.	Occ. D.	First contact	138	21 40 8	
28	II.	„	Bisection	„	21 43 23	21 43 0
28	II.	„	Last seen	„	21 45 28	
May 1	III.	Ecl. R.	First seen	„	22 15 36	22 16 2
1	I.	Occ. D.	First contact	131	23 43 19	
1	I.	„	Bisection	„	23 45 58	23 46 0
1	I.	„	Last seen	„	23 47 38	
2	I.	Tr. Ingr.	Ext. contact	„	21 6 39	
2	I.	„	Bisection	„	21 9 4	21 6 0
2	I.	„	Int. contact	„	21 11 19	
2	I.	Tr. Egr.	Int. contact	„	23 21 37	
2	I.	„	Bisection	„	23 24 6	23 25 0
2	I.	„	Ext. contact	„	23 27 1	
2	Shd. I.	Transit	On cent. merid.	„	23 16 43	
3	I.	Ecl. R.	First seen	175	21 43 31	21 43 34
8	III.	Occ. R.	Last contact	132	21 18 56	21 22 0
8	III.	Ecl. D.	Last seen	74	22 59 33	22 56 0
10	I.	Occ. D.	First contact	168	20 6 8	
10	I.	„	Bisection	„	20 8 28	20 7 0
10	I.	„	Last seen	„	20 9 38	
14	II.	Tr. Ingr.	Ext. contact	„	20 52 35	
14	II.	„	Bisection	„	20 55 30	20 56 0
14	II.	„	Int. contact	„	20 58 44	
15	III.	Occ. D.	First contact	132	21 37 52	
15	III.	„	Bisection	„	21 41 16	21 40 0
15	III.	„	Last seen	„	21 44 40	
16	II.	Ecl. R.	First seen	74	21 22 20	21 22 2
16	II.	„	Full brightness	„	21 26 36	
17	I.	Occ. D.	First contact	168	21 58 14	
17	I.	„	Bisection	„	22 1 4	22 1 0
17	I.	„	Last seen	„	22 2 33	
25	I.	Tr. Ingr.	Ext. contact	„	21 16 11	
25	I.	„	Bisection	„	21 18 16	21 16 0
25	I.	„	Int. contact	„	21 20 45	
26	I.	Ecl. R.	First seen	74	21 57 40	21 57 44

Day of Obs.	Satellite.	Phenomenon.	Phase.	Mag. Power.	G.M.T. of Observation.	Mean Time of *N. Almanac.*
1897.					h m s	h m s
June 26	I.	Tr. Egr.	Int. contact	168	20 16 9	
26	I.	"	Bisection	"	20 20 3	20 22 0
26	I.	"	Ext. contact	"	20 22 53	
July 1	II.	Occ. D.	First contact	"	21 14 28	
1	II.	"	Bisection	"	21 17 3	21 16 0
1	II.	"	Last seen	"	21 19 42	
4	I.	Ecl. R.	First seen	74	20 31 19	20 31 1
19	II.	"	First seen	"	20 33 16	20 32 44
19	II.	"	Full brightness	"	20 35 52	

Notes.

February 22–23.—Definition pretty good.

March 8.—Good definition.

March 25.—Sky beautifully clear, and images steady and well defined.

March 27.—Good definition.

March 30.—Images steady and fairly well defined.

April 1.—Good definition.

April 5.—Definition pretty good.

April 9.—Definition pretty good, but first phase unsatisfactory.

April 16.—The time of final disappearance doubtful to a second or two in consequence of the very slow fading of the satellite; the definition was good. The definition was also good at the ingress. Clouds prevented an observation of the reappearance from eclipse.

April 17.—Images very tremulous and badly defined, particularly at the last phase of the occultation. Definition pretty good at the eclipse, but full Moon present. In observing the first phase of the eclipse the planet was hidden by a bar of the micrometer eyepiece.

April 26.—Beautifully clear and definition good, but the twilight had scarcely disappeared. The first phase was observed as on the 17th. The square bar micrometer, which was in adjustment for the observation of Comet I., 1897 (Perrine), was employed from February 22 to April 26.

April 28.—Good definition.

May 1.—Definition good for both phenomena, except at the last phase of the occultation. Sky beautifully clear.

May 2.—Definition pretty good for the ingress and good for the egress. The transit of the shadow was observed by estimation only.

May 3.—Good definition.

May 8.—Definition pretty good for the occultation phase. For the eclipse the sky was beautifully clear and the definition good, but the Moon was present.

May 10.—Definition pretty good, but the second phase was observed late.

May 14.—Definition bad and images tremulous.

May 15.—Images pretty steady and well defined.

May 16.—Definition pretty good, but images rather tremulous, and the full Moon present.

May 17.—Definition good at first two phases, but bad at the last phase.

May 25.—Definition bad and images tremulous.

May 26.—Light clouds occasionally passing over the planet, but at the critical time it shone clear and bright.

June 26.—Definition pretty good.

July 1.—Bad definition; last phase extremely difficult to observe.

July 4.—Sky beautifully clear and Moon not far from planet. The images were greatly blurred and the observation was very unsatisfactory.

July 19.—Sky beautifully clear, but the images were unsteady and badly defined.

Except where otherwise stated, an occulting bar was not employed in the eclipse observations. The times given are the Windsor mean times of observation diminished by 10 hrs. 3 mins. 20·51 secs., and extend to the nearest second. The observations of full brightness in the eclipses are at the best only rough approximations. In determining these times the increasing light of the satellite was repeatedly compared with the other visible satellites.

Private Observatory, Windsor, N.S. Wales:
1898 *April* 18.

Ephemeris for Physical Observations of

Greenwich Noon.	P.	L−O.	B.	A−L.	*B*.	Q.	E.	Light Time.
1898.	°	°	°	°	°	°	°	m
June 27	321·16	143·13	−14·98	−35·17	−24·13	252·22	34·29	14·96
29	321·20	144·51	14·45	35·22	23·96	252·67	34·49	14·89
July 1	321·26	145·88	13·92	35·26	23·78	253·13	34·70	14·83
3	321·34	147·25	13·39	35·31	23·59	253·59	34·91	14·76
5	321·45	148·60	12·85	35·35	23·40	254·05	35·12	14·69
7	321·58	149·94	−12·31	−35·39	−23·19	254·51	35·32	14·61
9	321·74	151·28	11·76	35·44	22·97	254·98	35·53	14·54
11	321·92	152·60	11·21	35·47	22·74	255·47	35·73	14·47
13	322·13	153·92	10·66	35·50	22·50	255·96	35·93	14·40
15	322·36	155·23	10·10	35·53	22·25	256·46	36·12	14·33
17	322·61	156·53	−9·54	−35·56	−21·99	256·97	36·31	14·25
19	322·88	157·81	8·98	35·59	21·72	257·49	36·50	14·18
21	323·16	159·08	8·41	35·61	21·44	258·01	36·70	14·11
23	323·46	160·35	7·84	35·64	21·16	258·54	36·89	14·03
25	323·79	161·61	7·27	35·67	20·87	259·08	37·08	13·96
27	324·14	162·86	−6·70	−35·71	−20·57	259·62	37·26	13·88
29	324·51	164·10	6·14	35·74	20·26	260·16	37·43	13·80
31	324·90	165·33	5·58	35·77	19·94	260·71	37·61	13·71
Aug. 2	325·31	166·56	5·01	35·80	19·62	261·26	37·78	13·63
4	325·73	167·78	4·44	35·83	19·29	261·82	37·95	13·55
6	326·17	168·98	−3·87	−35·86	−18·96	262·38	38·13	13·47
8	326·63	170·18	3·31	35·89	18·62	262·94	38·29	13·39
10	327·10	171·38	2·75	35·92	18·27	263·50	38·45	13·30
12	327·58	172·57	2·19	35·95	17·91	264·06	38·61	13·21
14	328·08	173·76	1·63	35·99	17·55	264·62	38·76	13·12
16	328·60	174·94	−1·07	−36·03	−17·19	265·18	38·91	13·03
18	329·12	176·11	−0·52	36·07	16·82	265·74	39·06	12·94
20	329·65	177·27	+0·03	36·11	16·45	266·30	39·20	12·85
22	330·20	178·42	0·57	36·15	16·07	266·86	39·34	12·76
24	330·76	179·56	1·11	36·18	15·69	267·42	39·47	12·66
26	331·32	180·69	1·64	36·21	15·30	267·98	39·60	12·57
28	331·89	181·82	2·17	36·25	14·91	268·53	39·72	12·47
30	332·47	182·94	+2·70	−36·29	−14·51	269·08	39·84	12·38

Mars, 1898. By A. C. D. Crommelin.

Greenwich Noon.		Appar. Diam.	Defect of Illumination. q	Central Meridian. ω_0	Passage of Zero Meridian.			
1898.		"	"	°	h	m	h	m
June	27	5·33	0·46	4·53	...	...	23	41
	29	5·35	0·46	344·95	1	2	0	22
July	1	5·37	0·47	325·38	2	22	1	42
	3	5·39	0·48	305·82	3	42	3	2
	5	5·42	0·49	286·27	5	3	4	23
	7	5·46	0·50	266·73	6	23	5	43
	9	5·49	0·51	247·20	7	43	7	3
	11	5·52	0·51	227·67	9	4	8	23
	13	5·55	0·52	208·15	10	24	9	44
	15	5·58	0·53	188·64	11	44	11	4
	17	5·61	0·54	169·14	13	5	12	25
	19	5·65	0·55	149·65	14	25	13	45
	21	5·68	0·56	130·17	15	45	15	5
	23	5·71	0·57	110·71	17	5	16	25
	25	5·74	0·58	91·26	18	25	17	45
	27	5·77	0·59	71·82	19	45	19	5
	29	5·80	0·59	52·39	21	5	20	25
	31	5·83	0·60	32·97	22	24	21	45
Aug.	2	5·87	0·61	13·55	23	44	23	4
	4	5·91	0·62	354·13	0	24	...	...
	6	5·95	0·63	334·72	1	44	1	4
	8	5·98	0·64	315·32	3	4	2	24
	10	6·02	0·65	295·93	4	23	3	44
	12	6·06	0·66	276·54	5	43	5	3
	14	6·10	0·67	257·16	7	2	6	22
	16	6·14	0·68	237·79	8	22	7	42
	18	6·18	0·69	218·43	9	41	9	2
	20	6·22	0·70	199·08	11	1	10	21
	22	6·27	0·71	179·74	12	21	11	41
	24	6·31	0·72	160·40	13	40	13	0
	26	6·36	0·73	141·07	14	59	14	20
	28	6·40	0·74	121·75	16	19	15	39
	30	6·45	0·75	102·44	17	38	16	58

Greenwich Noon.		P.	L−O.	B.	A−L.	*B*.	Q.	R.	Light Time.
1898.		°	°	°	°	°	°	°	m
Sept.	1	333·06	184·06	+3·22	−36·33	−14·11	269·62	39·96	12·28
	3	333·66	185·17	3·73	36·37	13·71	270·16	40·07	12·18
	5	334·26	186·27	4·24	36·41	13·30	270·70	40·18	12·08
	7	334·87	187·37	4·75	36·46	12·89	271·24	40·28	11·98
	9	335·49	188·47	+5·25	−36·52	−12·48	271·77	40·37	11·88
	11	336·11	189·55	5·73	36·56	12·07	272·30	40·46	11·78
	13	336·73	190·63	6·20	36·61	11·65	272·81	40·54	11·67
	15	337·36	191·70	6·67	36·65	11·23	273·32	40·61	11·56
	17	337·99	192·76	7·13	36·69	10·81	273·82	40·67	11·46
	19	338·63	193·81	+ 7·59	−36·73	−10·39	274·31	40·73	11·35
	21	339·27	194·86	8·03	36·78	9·97	274·80	40·78	11·24
	23	339·90	195·90	8·47	36·82	9·55	275·28	40·82	11·13
	25	340·52	196·93	8·90	36·85	9·12	275·75	40·85	11·02
	27	341·15	197·94	9·32	36·87	8·69	276·21	40·88	10·91
	29	341·78	198·94	+ 9·73	−36·89	− 8·26	276·65	40·89	10·80
Oct.	1	342·40	199·94	10·13	36·91	7·83	277·08	40·89	10·68
	3	343·02	200·93	10·52	36·93	7·39	277·50	40·88	10·57
	5	343·63	201·91	10·91	36·94	6·96	277·92	40·86	10·45
	7	344·23	202·87	11·28	36·94	6·53	278·33	40·83	10·33
	9	344·84	203·82	+11·64	−36·93	− 6·10	278·73	40·79	10·21
	11	345·45	204·77	12·00	36·92	5·67	279·12	40·74	10·09
	13	346·05	205·70	12·34	36·90	5·23	279·49	40·68	9·97
	15	346·64	206·61	12·67	36·87	4·80	279·85	40·59	9·85
	17	347·22	207·51	12·98	36·83	4·37	280·19	40·49	9·72
	19	347·79	208·40	+13·28	−36·79	− 3·93	280·52	40·38	9·60
	21	348·35	209·27	13·58	36·73	3·50	280·84	40·25	9·48
	23	348·90	210·12	13·86	36·66	3·06	281·15	40·10	9·35
	25	349·45	210·96	14·13	36·57	2·63	281·44	39·93	9·23
	27	349·98	211·78	14·38	36·47	2·20	281·71	39·74	9·11
	29	350·49	212·56	+14·62	−36·33	− 1·77	281·97	39·53	8·99
	31	350·98	213·31	14·85	36·17	1·35	282·21	39·30	8·86
Nov.	2	351·46	214·04	15·07	35·99	0·93	282·45	39·04	8·73
	4	351·92	214·74	15·28	35·79	0·50	282·67	38·77	8·61
	6	352·35	215·42	15·44	35·57	0·07	282·87	38·48	8·48
	8	352·76	216·06	+15·60	−35·31	+ 0·35	283·06	38·16	8·35
	10	353·14	216·67	+15·74	−35·03	+ 0·77	283·24	37·81	8·23

Greenwich Noon.		Appar. Diam.	Defect of Illumination. q	Central Meridian. ω_0	Passage of Zero Meridian.			
1898.		″	″	°	h	m	h	m
Sept.	1	6·50	0·76	83·13	18	58	18	18
	3	6·56	0·77	63·83	20	17	19	38
	5	6·61	0·78	44·53	21	37	20	57
	7	6·66	0·79	25·24	22	57	22	17
	9	6·72	0·80	5·95	...	...	23	36
	11	6·78	0·81	346·67	0	55	0	16
	13	6·84	0·82	327·40	2	14	1	35
	15	6·90	0·83	308·14	3	33	2	54
	17	6·97	0·84	288·89	4	52	4	13
	19	7·04	0·85	269·65	6	11	5	31
	21	7·12	0·86	250·42	7	30	6	50
	23	7·20	0·87	231·19	8	49	8	9
	25	7·27	0·89	211·97	10	8	9	28
	27	7·34	0·90	192·76	11	27	10	47
	29	7·41	0·91	173·56	12	45	12	6
Oct.	1	7·50	0·92	154·37	14	5	13	25
	3	7·57	0·93	135·20	15	23	14	44
	5	7·64	0·93	116·04	16	42	16	2
	7	7·72	0·94	96·89	18	0	17	21
	9	7·81	0·95	77·75	19	19	18	40
	11	7·91	0·96	58·62	20	38	19	59
	13	8·02	0·97	39·51	21	57	21	18
	15	8·12	0·97	20·41	23	16	22	36
	17	8·23	0·98	1·32	...	...	23	55
	19	8·33	0·99	342·24	1	13	0	34
	21	8·43	1·00	323·18	2	31	1	52
	23	8·54	1·00	304·14	3	49	3	10
	25	8·65	1·01	285·13	5	7	4	28
	27	8·77	1·01	266·15	6	25	5	46
	29	8·89	1·01	247·18	7	43	7	4
	31	9·02	1·02	228·23	9	1	8	22
Nov.	2	9·15	1·02	209·31	10	19	9	40
	4	9·29	1·02	190·42	11	37	10	58
	6	9·42	1·02	171·56	12	55	12	16
	8	9·56	1·02	152·73	14	12	13	33
	10	9·70	1·02	133·94	15	29	14	51

The ephemeris has been constructed with the same constants as those employed by Mr. Marth in his ephemeris for the last opposition (*Monthly Notices*, lvi. 7, p. 394). The position of the north pole of *Mars* for 1898·0 is taken as R.A. 317°·15, N.P.D. 37°·43, this being the value deduced by Struve from observations of the satellites: it differs considerably from values deduced from observations of markings on the planet. The following are the three most recent determinations by this method, all reduced to 1898·0:—

	R.A.	N.P.D.	
Schiaparelli	318°·27	36°·31	Mean value R.A. 318°·35, N.P.D. 36°·37.
Lohse, 1883	318°·34	36°·63	
Lohse, 1893	318°·45	36°·16	

I shall be glad of the opinions of observers as to the advisability of continuing to use Struve's value, or substituting the mean of the other three.

P denotes the position-angle of the axis of *Mars*, $L - O + 180°$ the longitude of the Earth referred to the plane of *Mars'* equator, and reckoned from O, the point of the vernal equinox of *Mars'* northern hemisphere, $\Lambda - O + 180°$ the corresponding quantity for the Sun, B, *B* the latitudes of the Earth and Sun reckoned from the plane of *Mars'* equator, Q the position-angle of the greatest defect of illumination, q the amount of the greatest defect of illumination, E the areocentric angle between Earth and Sun.

The diameter of the planet at distance unity is assumed (as before) to be 9″·60, that used in the *Nautical Almanac* being 9″·36.

The zero meridian and period of rotation have been carried on unchanged from Mr. Marth's last ephemeris, the assumed sidereal rotation in 24 hours being 350°·89202.

The times of passage of the zero meridian are given approximately. Where greater accuracy is required, the time may be deduced by interpolating between two successive tabulated values of the central meridian at noon.

The winter solstice of *Mars'* northern hemisphere occurred 1898 May $31^d·7$, and the spring equinox occurs 1898 November $6^d·3$.

Benvenue, Ulundi Road, Blackheath, S.E.:
1898 *June* 20.

Erratum in Mr. Anderson's paper, MONTHLY NOTICES, vol. lviii. p. 380, note to observation of March 8:—

For ζ *Tauri* read ξ *Tauri*.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Enquiry for Letters of Gauss.

A letter has been received from Professor Stäckel, of Kiel University, asking that publicity may be given to the following request :—

The *Königliche Gesellschaft der Wissenschaften zu Göttingen* hopes shortly to complete the edition of the works of Carl Friedrich Gauss. The *Gesellschaft* therefore requests all those persons or Societies who are in possession of any manuscripts or information of interest concerning Gauss, kindly to communicate such material.

The Sidereal System Revised in 1898. By Maxwell Hall, M.A.

Up to the present time the solar orbit has been assumed to be circular, and both Γ and Λ have been taken equal to zero; but it will be found that the theory is considerably improved by taking $\Lambda = -1$ as a first approximation.

Referring to the formulæ for computation, *Monthly Notices*, vol. lvii. pp. 360, 370, for $v^2 = Fr_0^2$, we now have

$$\rho_0 = \frac{2V(au - b + H\Pi V)}{c^2 + u^2 - \overline{\Pi^2 V^2} + \Lambda \,.\, \overline{\varpi^2 V^2} \,.\, \Pi^2 r_0^2}.$$

The last term in the denominator becomes of great importance among those stars whose computed parallaxes are large; and the results of the last general computation clearly show that such a controlling term is required.

We shall now recompute all parallaxes and radial velocities on the supposition that $v^2 = \mathrm{F}r_0^2$; but, when necessary, on the supposition that $v^2 = \mathrm{F}r_0$, the circumstance being duly noted, as recommended in the last revision referred to above, p. 369.

We now require an expression for ρ_0, when $v^2 = \mathrm{F}r_0$; and as the expression for ρ_0 when $v^2 = \mathrm{F}r_0^2$, as given above, leads to unnecessary complications—such, for instance, as that in some cases the numerator and denominator of ρ_0 are both negative—we shall take a simpler form.

Thus

$$v^2 = \mathrm{F}r_0,$$

and in the case of the Sun,

$$\mathrm{V}^2 = \mathrm{FR}_0 + \mathrm{AV}^2,$$

or

$$\mathrm{F} = \Pi \mathrm{V}^2(1 - \mathrm{A}).$$

And as we have taken $\Pi = 0{\cdot}02$, $\mathrm{V} = 5$, and $\mathrm{A} = -1$, it follows that $\mathrm{F} = 1$; but we shall retain F in the equations, as it is not likely that 1 will be its final value.

Now, referring to the fundamental equations

$$v^2 = \mathrm{V}^2 + (c^2 + u^2)\rho_0^2 - 2\mathrm{V}(au - b)\rho_0;$$

therefore

$$(c^2 + u^2)\rho_0^2 - 2\mathrm{V}(au - b)\rho_0 = \mathrm{F}r_0 - \mathrm{V}^2,$$

or

$$(c^2 + u^2)\rho_0 - 2\mathrm{V}(au - b) = \varpi(\mathrm{F}r_0 - \mathrm{V}^2),$$

whence

$$\rho_0 = \frac{2\mathrm{V}(au - b) + \varpi(\mathrm{F}r_0 - \mathrm{V}^2)}{c^2 + u^2}.$$

And, collecting our expressions as on p. 370, *Monthly Notices*, vol. lvii., we have

$$\mathrm{F} = \Pi \mathrm{V}^2(1 - \mathrm{A})$$

$$v^2 = \mathrm{F}r_0;$$

$$r_0 = \sqrt{\mathrm{R}_0^2 + \rho_0^2 + 2\mathrm{HR}_0\rho_0};$$

$$u = \frac{\mathrm{K} + a\Pi\mathrm{V} + \varpi\Gamma\mathrm{V}}{\mathrm{H} + \Pi\rho_0};$$

$$\Gamma = \mathrm{L}\lambda + \mathrm{M}\mu + \mathrm{N}\nu;$$

$$\rho_0 = \frac{2\mathrm{V}(au - b) + \varpi(\mathrm{F}r_0 - \mathrm{V}^2}{c^2 + u^2};$$

$$\frac{d\rho}{dt} = -u\rho_0;$$

$$\varpi = \frac{1}{\rho_0}.$$

From the former list of stars we shall omit No. 2, α Argûs

(*Canopus*), whose proper motions are zero; but to that list we must add the following:—

Star	Mag.	R.A. 1850	P.M. in R.A.	N.P.D. 1850	P.M. in N.P.D.
		h m s	s	° ′	″
α Eridani	0·5	1 32 7	+0·0080	148 0	+0·070
α Scorpii	1·1	16 20 13	− ·0022	116 6	+ ·028
β Centauri	1·2	13 53 17	− ·0100	149 39	+ ·050
α Crucis	1·3	12 18 18	− ·0060	152 16	+ ·040
α Piscis Aust.	1·3	22 49 21	+ ·0232	120 25	+ ·159
β Crucis	1·4	12 39 0	− ·0090	148 52	+ ·030
α Gruis	1·9	21 58 45	+ ·0110	137 41	+ ·150
β Hydri	2·7	0 17 47	+ ·7200	168 6	− ·320
δ Ursæ Maj.	3·4	12 7 59	+ ·0133	32 8	− ·004
η Aquilæ	4·1	19 44 50	− ·0017	89 23	+ ·003
β Comæ	4·4	13 4 52	− ·0605	61 22	− ·897
31 Aquilæ	5·3	19 17 49	+0·0487	78 22	−0·651

The above P.M.s are those of Dr. Auwers and those of Dr. Stone, as adopted by the *Nautical Almanac*. The following are the results of observation:—

Star.	″	Parallax, &c.
α Eridani		Gill.
α Scorpii	0·021	Finlay, *Monthly Notices*, vol. lviii. p. 172.
β Centauri	0·046	Gill. " " "
α Crucis		"
α Piscis Aust.	0·130	" " " "
β Crucis		"
α Gruis	0·015	" " " "
β Hydri		"
δ Ursæ Maj.	0·09	Bruno Peter, *Nature*, vol. lvii. p. 546.
η Aquilæ	$\frac{d\rho}{dt} = -1.$	Belopolsky, " " p. 353.
β Comæ	0·11	Bruno Peter, " " p. 546.
31 Aquilæ	0·06	" " " "

It will be convenient to arrange the results of the recomputation in two Tables, the first containing satisfactory, or fairly satisfactory, results, from stellar orbits more or less circular; and the second containing failures probably due to elliptic, or highly elliptic, orbits.

TABLE I.

No.	Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	Computed. ϖ	Computed. $\frac{d\rho}{dt}$
		″		″	
1	α Canis Maj. (*Sirius*)	0·27	0?	0·17	0
3	α Boötis (*Arcturus*)	0·07	− 9	0·31	− 9
4	α Centauri	0·72	...	0·65	− 3
5	α Aurigæ (*Capella*)	0·07	+ 7	0·06	+ 6
6	β Orionis (*Rigel*)	0·03	+ 4	0·04	+ 11
7	α Lyræ (*Vega*)	0·12	− 9	0·14	− 11
*	α Eridani (*Achernar*)	...	...	0·01	− 1
8	α Canis Min. (*Procyon*)	0·23	+ 2	0·11	+ 5
9	α Orionis	0·02	+ 6	0·04	+ 10
10	α Aquilæ (*Altair*)	0·20	− 8	0·26	− 10
11	α Tauri (*Aldebaran*)	0·10	+ 11	0·04	+ 9
12*	α Virginis (*Spica*)	...	− 4	0·00	− 2
*	α Scorpii (*Antares*)	0·02	...	0·00	− 4
*	β Centauri	0·05	...	0·00	+ 1
14	α Leonis (*Regulus*)	0·09	+ 1	0·02	+ 6
*	α Crucis	...	...	0·00	+ 3
	α Piscis Aust. (*Fomalhaut*)	0·13	...	0·06	− 6
*	β Crucis	...	...	0·00	+ 2
15	α Cygni	0·01	− 7	0·02	− 8
16	α Gemin. (*Castor*)	...	− 6†	0·49	− 4
18	ε Orionis	...	+ 6	0·04	+ 11
20*	ε Ursæ Maj.	0·08	− 1?	0·02	− 4
21	α Persei	0·09	− 6	0·03	− 1
22	β Tauri	0·06	+ 2†	0·04	+ 8
23	α Ursæ Maj.	0·05	− 9	0·20	− 8
24*	η Ursæ Maj.	...	− 6	0·01	− 5
	α Gruis	0·02	...	0·01	− 2
25*	β Aurigæ	0·06	− 6	0·08	− 4
26	α Andromedæ	0·06	− 4?	0·03	− 1
27	α Ursæ Min. (*Polaris*)	0·05	− 6	0·03	− 9
28	γ Andromedæ	...	− 3	0·00	0
29	α Arietis	0·08	− 4	0·03	+ 3
31	γ Cassiopeiæ	0·01	− 4	0·02	− 4
32	δ Andromedæ	0·07	+ 2	0·03	+ 1

* $v^2 = Fr_0$. † Potsdam.

No.	Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	Computed. ϖ	Computed. $\frac{d\rho}{dt}$
		″		″	
34*	γ Leonis	...	− 9	0·13	− 3
35	β Leonis	0·03	− 3	0·03	+ 1
36*	ζ Ursæ Maj.	...	− 7†	0·02	− 4
40	γ Cygni	0·10	− 3	0·02	− 9
41	β Cassiopeiæ	0·16	0	0·06	− 4
42	α Cassiopeiæ	0·04	− 3	0·02	− 4
43	β Persei (*Algol*)	0·05	0	0·01	+ 2
44*	β Ursæ Maj.	0·08	0	0·02	− 1
45	γ Ursæ Maj.	0·10	− 5†	0·04	− 3
47*	ϵ Pegasi	0·08	+ 2†	0·05	+ 2
48	α Pegasi	0·08	0†	0·03	+ 2
49*	ϵ Boötis	...	− 4	0·00	3
50	α Cephei	0·06	− 14	0·03	− 9
51	β Pegasi	...	+ 1	0·05	− 2
	β Hydri	...	...	0·22	+ 7
52*	β Libræ	...	− 2	0·01	− 4
53*	α Serpentis	...	+ 5	0·03	+ 1
54	ϵ Cygni	0·13	...	0·03	− 7
55*	δ Leonis	...	− 3	0·04	− 4
56*	β Herculis	...	− 8	0·01	− 8
60	δ Herculis	0·08	...	0·01	− 11
*	δ Ursæ Maj.	0·09	...	0·03	− 3
62	η Cassiopeiæ	0·31	...	0·11	− 3
64	10 Ursæ Maj.	0·20	...	0·05	+ 5
65	70 (p) Ophiuchi	0·22	...	0·17	− 10
66	θ Cassiopeiæ	0·23	...	0·04	+ 2
67	e Eridani	0·14	...	0·56	+ 12
68	o^2 Eridani	0·19	...	0·57	+ 1
	β Comæ	0·11	...	0·38	+ 3
69	δ Ursæ Min.	0·03	...	0·03	− 9
70	δ Equulei	0·04	...	0·06	+ 3
71	σ Draconis	0·25	...	0·38	− 3
72	ν^2 Draconis	0·28	...	0·11	− 13
73	ν^1 Draconis	0·32	...	0·11	− 11
75	61 Cygni	0·43	...	0·67	− 7
76	μ Cassiopeæ	0·18	...	0·32	− 2
77	ϵ Indi	0·22	...	0·45	+ 6

* $v^2 = Fr_0$. † Potsdam.

No.	Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	Computed. ϖ	Computed. $\frac{d\rho}{dt}$
		$''$		$''$	
78	Cephei 51 (Hev.)	0·03	...	0·04	− 8
79	3077 Bradley	0·18	...	0·21	− 4
80	85 Pegasi	0·06	...	0·12	− 1
81	20 Leonis Min.	0·06	...	0·09	−10
83	1618 Groombridge	0·25	...	0·69	+ 5
84	Σ 1516	0·15	...	0·17	−10
87	Σ 2398	0·35	...	0·96	+ 2
88	34 Groombridge	0·31	...	0·30	− 1

TABLE II.

No.	Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	Computed. ϖ	Computed. $\frac{d\rho}{dt}$
		$''$		$''$	
13	β Gemin. (*Pollux*)	0·06	− 7 ?	...	...
17	γ Orionis	...	+ 2	0·04	+10
19	ζ Orionis	...	+ 3	0·04	+10
30	γ Geminorum	...	− 4	0·10	+10
33	δ Orionis	...	0	0·4	+11
37	β Ursæ Min.	0·02	+ 3	0·04	−10
38	α Ophiuchi	...	0 ?	0·02	− 5
39*	α Coronæ	...	+ 7	0·02	− 4
46	γ Draconis	0·07	− 2	0·04	−12
57	ι Ursæ Maj.	0·13	...	0·84	− 6
58	θ Ursæ Maj.	0·05	...	1·54	− 7
59	α Herculis	0·05	...	...	...
61	π Herculis	0·11	...	1·25	−12
63	η Herculis	0·40	...	...	...
	η Aquilæ	...	− 1	0·04	− 9
74	ζ Toucani	0·06	...	1·72	+ 9
	31 Aquilæ	0·06	...	0·46	−10
82	1830 Groombridge	0·13	...	2·67	− 6
85	21 185 Lalande	0·46	...	1·50	− 7
86	9352 Lacaille	0·28	...	2·30	− 5
89	21 258 Lalande	0·23	...	2·32	+ 4
90	17 415 Oelt. Argel.	0·20	...	1·40	+ 2
91	11 677 Oelt. Argel.	0·18	...	1·25	− 9

By comparing Tables I. and II. we arrive at the following results :—

1. The present revision gives about 20 per cent. of failure,

* $v^2 = Fr_0$.

while the last revision gave about 40 per cent.; and in consequence the introduction of Λ has proved a marked success.

2. But the percentage of failure is not constant throughout the list; the stars are arranged according to their magnitudes, and while the percentage is very small among the brighter stars, it increases as the stars diminish in brightness; and among the very faint stars (which were, of course, picked out for observation of parallax on account of their very large proper motions), there are many failures.

No. of Stars Computed.	No. of Failures.	Percentage of Failure.
10	0	0
20	1	5
30	3	10
40	5	12
50	8	16
60	9	15
70	13	19
80	15	19
90	17	19
100	21	21

3. Now when it is remembered that a large number of the brighter stars give correct results in *both* parallax and radial velocity, there can be no doubt that as far as our problem is concerned the brighter stars should be observed for parallax and radial velocity instead of the fainter stars having abnormally large proper motions; and as the numerical work is now becoming very heavy, it seems advisable to omit at present the further computation of stars of the latter class.

4. In the last revision of 1896 the results from $v^2 = \mathrm{F}r_0^2$ were slightly preferable to those from $v^2 = \mathrm{F}r_0$; but it appears from a number of the brighter southern stars at great distances from the centre that we are now obliged to give the preference to $v^2 = \mathrm{F}r_0$.

From certain investigations I made many years ago on the number and the distribution of the stars, it appears that they really do diminish in number with the distance from the Sun, which was assumed to be not far from the centre; and I believe it was this effect which once led to the idea of the gradual extinction of light in its passage through space.

It therefore appears advisable to use the equation for ρ_0 resulting from $v^2 = \mathrm{F}r_0$ in our further investigations, as given above on p. 474.

This change in the law of force necessitates the recomputation of the coefficients of the correction $\Delta\lambda$, $\Delta\mathrm{L}$, &c., to be applied to the adopted values λ, L, &c., as given on p. 371 of the last revision. But the calculation of the coefficients by such formulæ is difficult and liable to error. It will, perhaps, be better to proceed in the manner suggested by Lieutenant Stratford for the

correction of the elements of the orbit of Halley's Comet. (Appendices to various *Nautical Almanacs*, p. 196.)

Thus to find $\frac{d\varpi}{dV}$ for any star, increase V by unity, and recompute; this will give the change in ϖ corresponding to a change of $+1$ in V, or approximately $\frac{d\varpi}{dV}$.

Similarly, $\frac{d\varpi}{d\Lambda}$ and $\frac{d\varpi}{d\Pi}$ may be found.

But instead of finding $\frac{d\varpi}{d\lambda}$, &c., we must increase the apex 1° in R.A., the N.P.D. being unchanged; and by computing the new λ and μ, and the new ϖ, we get $\frac{d\varpi}{d\alpha}$. Similarly by increasing the apex 1° in N.P.D., the R.A. remaining unchanged, and by computing the new λ, μ, and ν, and the new ϖ, we get $\frac{d\varpi}{d\beta}$.

And similarly we must treat the position of the Sun as seen from the Centre, and get $\frac{d\varpi}{d\mathcal{R}}$ and $\frac{d\varpi}{d\Delta}$.

Of course, the same computations will apply to a system of corrections based upon radial velocity as well as upon parallax. And then from the two systems we get equations similar to

$$\mathfrak{A}\,.\,\Delta\lambda + \mathfrak{B}\,.\,\Delta\mu + \&c. + \Delta\varpi = 0$$
$$\mathfrak{A}\,.\,\Delta\lambda + \mathfrak{B}\,.\,\Delta\mu + \&c. + \Delta\frac{d\rho}{dt} = 0,$$

where $\Delta\lambda$, $\Delta\mu$, &c., are the corrections to be applied to the assumed values of λ, μ, &c., and where $\Delta\varpi$ is the observed minus the computed parallax, and where $\Delta\frac{d\rho}{dt}$ is the observed minus the computed radial velocity.

Jamaica:
1898 *June* 2.

Observations of Jupiter in 1898. By W. F. Denning.

During the period from 1898 March to July I observed *Jupiter* on 51 nights in my 10-inch Browning-With reflector. I usually employed one of Steinheil's "monocentric oculars," consisting of three cemented lenses and giving a power of 312. Occasionally I used the single lens of a Huygenian magnifying 252, and more rarely one of Browning's achromatic eye-pieces with a power of 488. But, ordinarily, the power of 312 possessed a marked advantage over the others.

I obtained about 280 estimated transits of the various markings on the planet, with a view to finding the individual

velocities of the currents in which they were situated. The results for each object observed are given in a tabular form at the end of this paper. About eight different currents were manifested, of which the following is a summary:—

Approx. Latitude.	Number of Objects seen.	Description of Objects.	Period of Rotation. h m s
$+39^{\circ}$	1	Dark oval spot on NN. temp. belt	9 55 47·8
+33	1	Dark oval spot in bright zone	9 55 52·5
+15	3	Dark oval spots	9 55 26·3
Region of Equator	23	Dark and white spots	9 50 23·6
−21	1	Great red spot	9 55 41·8
−30	4	Dark and white spots on S. temp. belt	9 55 20·5
−35	2	White spots in zone S. of preceding	9 55 14·0
−40	2	Dark spots	9 55 8·6

The latitudes are by estimation. It is possible that the first two objects may represent one current only, the difference in their rotation periods being less than 5 seconds. It is noteworthy that these objects in the N. hemisphere were the only ones observed which were moving more slowly than the great red spot. The spot in Lat. $+39^{\circ}$, which was really a swell or thickening in the NN. temp. belt, could not be followed after May 23; it had lengthened out, and its material appeared to be in process of distribution along the belt. The oval spot in Lat. $+33^{\circ}$ survived until early in July, when, however, it was seen with difficulty.

With reference to the equatorial spots, they were so numerous, subject to so many variations in form and distinctness, and influenced by such different, and apparently irregular, velocities, that it was often hard to identify the same objects with certainty. The 23 markings included in the table are chiefly selected as being the most conspicuous of their class, and affording satisfactory means of identification. It will be observed, on comparing the rotation periods for the individual spots in this current, that the motion was far from being equable, and that it exhibited large discordances in different longitudes. The extremes were those of a dark spot (No. 3) in $\lambda\, 29^{\circ}\!\cdot\!2$ on June 11, rotation period $9^{h}\ 50^{m}\ 33^{s}\!\cdot\!2$, and of a similar spot (No. 19) in $\lambda\, 300^{\circ}\!\cdot\!5$ on May 8, rotation period $9^{h}\ 50^{m}\ 16^{s}\!\cdot\!9$. The numerous other objects circulating along this region presented a variety of periods between the extremes mentioned. This difference in relative velocities induced some complications of a puzzling character, for it enabled certain spots to overtake and pass others moving at slower rates. Thus No. 11 in the table of equatorial spots was east of No. 10 in April, but apparently passed it in May, and was afterwards placed on its western side. No. 23 may be regarded as a special object, inasmuch as it was situated on the N. equatorial belt, but it moved at about the same rate as that shown by a mean of all the other equatorial spots in the table which were placed on the N. side of the S. equatorial belt.

The mean rotation period of $9^h\ 50^m\ 23^s{\cdot}6$ is $6^s{\cdot}4$ shorter than the adopted period ($9^h\ 50^m\ 30^s$) on which system I. in the ephemerides is based. It proves that the velocity of the equatorial current of *Jupiter* received considerable acceleration between the spring of 1897 and that of 1898. From 8 spots observed at the former season Mr. A. Stanley Williams deduced a mean rotation period of $9^h\ 50^m\ 34^s{\cdot}6$ (*Monthly Notices*, 1897 November, p. 13), which is exactly 11 seconds greater than the mean of my own observations in 1898. It would appear, therefore, that the equatorial current, after slackening from $9^h\ 50^m$ in 1879 to $9^h\ 50^m\ 34^s{\cdot}6$ in 1897, has now markedly increased its rate. This has varied as follows, according to previous observations here :—

	h	m	s
1880	9	50	5·8
1881	9	50	8·8
1882	9	50	11·4
1885	9	50	14·3
1886	9	50	22·8
1895	9	50	34·3
1898	9	50	23·6

As to the great red spot, it has recently been exceedingly faint. The *f* side was the plainest, but the complete oval outline of this marking was distinctly seen on but one occasion this year, when the image was beautifully defined and very steady. On March 22, and on a few subsequent occasions when fairly good glimpses were obtained, I remarked that the red spot did not appear to be symmetrically placed within the dip or bay in the S. side of the S. equatorial belt. The W. side or *p* shoulder of the bay was, however, flatter than the E. side, and moreover there was a very bright streak curving round the N. *p* side of the spot, and extending from that region to the planet's W. limb. This would naturally induce the impression that the spot was a little E. of the centre; I believe, however, even though the circumstances favoured a mistaken view, that the spot decidedly leaned to the *f* side, and the Rev. T. E. R. Phillips, of Yeovil, noticed the same thing on several occasions.

This configuration is not new, for it was noticed here on various nights during the oppositions of 1895 and 1897, but particular attention was not paid to it. It is a point which can only be settled by micrometric measurements, but the present extremely feeble aspect of this marking must render these very difficult. The motion of the spot appears to have further slackened, but only in a slight degree. In July the middle of the spot was in $\lambda\, 28°$, so that it was seen at mid-transit 46 minutes after the passage of the zero meridian of System II. in Mr. Crommelin's ephemerides (*Monthly Notices*, 1898 April). The values referred to ($\lambda\, 28° = 46^m$) represent the cumulative effect of the difference between the rate of motion of the red spot and the period of $9^h\ 55^m\ 40^s{\cdot}63$, upon which System II. is

based, since the summer of 1894, when the position of the red spot coincided with that of the zero meridian. In point of fact, the mean rotation period of the spot during the four years (nearly) from 1894 August 10 to 1898 July 30 (3,504 rotations) was $9^h\ 55^m\ 41^s{\cdot}4$, or $0^s{\cdot}78$ greater than the period adopted in System II.

There were visible three dark, elongated spots,* just exterior to the N. equatorial belt, and situated on a very delicate, narrow belt, in about Lat. $+15°$. These rotated at an average rate of $15\frac{1}{2}$ seconds less than that of the red spot at the same period. Relatively to the position of the latter these markings would, therefore, complete a revolution round *Jupiter* in 954 days, while the equatorial spots have recently occupied only $46\frac{1}{2}$ days. S. of the *f* ends of the three objects alluded to, and touching the N. side of the N. equatorial belt, there were bright spots which maintained their positions, and were at times strikingly brilliant. The *p* ends of the dark spots sometimes appeared bent abruptly to S., and in actual contact with the equatorial belt, but when definition was good the junction could not be confirmed, and the impression of its existence seemed due to the fact that the bright spots at the *f* ends intensified the division in that part, while the more dusky space between the *p* ends and the belt brought about the apparent coalescence of the objects, especially on a night when definition was indifferent.

The white and dark spots in Lat. $-30°$ seem to have changed their rate of motion very little, if at all, from that observed in previous years, when the rotation period was about $9^h\ 55^m\ 18^s$. Further south the spots are influenced by a much swifter current, but they are subject to such variations, and often nearly obliterated by inferior definition, that it is difficult to secure a sufficient number of really accurate observations to enable their exact periods to be ascertained. Quite possibly the two pairs of spots, in Lat. $-35°$ and $-40°$ respectively, may be situated in the same current, with a mean period of about $9^h\ 55^m\ 11^s$.

In determining the rotation periods in the following table I have compared two or three of the earliest with a similar number of the latest transits of the same object when the observations were sufficiently numerous for that purpose. In cases where a spot was observed for position on very few occasions, the first and last transits were utilised, and, in deriving the results, the more doubtful observations were rejected. The longitudes of the spots exterior to the equatorial belts were computed with reference to the zero meridian of System II., and the longitudes of the equatorial spots were based on System I. of Mr. Crommelin's ephemerides in *Monthly Notices*, 1897 November and 1898 January.

* Several additional markings of similar character and position were seen early in the opposition by Herr Fauth at Landstuhl, and at a later period by Mr. A. Stanley Williams at Brighton. The three objects observed at Bristol appear, however, to have been the most conspicuous and durable, and to have attracted the notice of a large number of observers.

Rotation Periods of Markings Outside the Equatorial Region of Jupiter, 1898.

No.	Description of Object.	Approximate Latitude.	Mean Longitude.	Mean Date.	Whole Period of Observation.		Length of Interval.	Rot. t'ons.	Period of Rotation.	No
					h m	h m	d h m		h m s	
1	Dark oval spot on belt	+39°	285°·8	May 5	April 17, 9 18	May 23, 9 14	35 23 56	101	9 55 47·8	1
2	Dark oval spot in bright zone . . .	+33	280 9	May 20	April 7, 10 39	July 3, 8 22	86 21 43	210	9 55 52 5	2
3	Dark oval spot	+15	110 8	May 13	Mar. 23, 9 25	July 4, 8 40	102 23 15	249	9 55 27·7	3
4	„	+15	238·4	June 1	April 17, 8 32	July 17, 8 1	90 23 29	220	9 55 26·3	4
5	„	+15	287·3	May 15	Mar. 14, 12 5	July 17, 9 10	124 21 5	302	9 55 24·8	5
6	Great red spot	−21	26·8	May 26	Mar. 22, 10 43	July 30, 8 29	129 21 28	314	9 55 41 8	6
7	White spot on S. temp. belt . . .	−30	1·8	May 11	April 15, 10 12	June 7, 8 20	52 22 8	128	9 55 21·7	7
8	„ „ „ . . .	−30	11·7	June 1	May 14, 9 18	June 19, 8 40	35 23 21	87	9 55 21·6	8
9	„ „ „ . . .	−30	127·9	May 13	April 4, 9 53	June 22, 9 3	78 23 10	191	9 55 19·4	9
10	Dark mass on S. temp. belt	−30	137·9	June 8	May 15, 8 46	July 2, 7 51	47 23 5	116	9 55 19 5	10
11	White spot in zone S. of S. temp. belt	−35	157·7	April 24	April 4, 10 30	May 15, 8 36	40 22 6	99	9 55 14·4	11
12	„ „ „	−35	297 0	May 25	April 22, 9 25	June 28, 8 43	66 23 18	154	9 55 13·7	12
13	Dark ellipse	−40	126·5	May 19	April 16, 9 57	June 22, 8 47	66 22 50	154	9 55 9·5	13
14	Dark spot	−40	291·9	May 29	April 22, 9 25	July 5, 9 13	73 23 48	179	9 55 7·7	14

Notes.

1. This object was seen by Dr. A. A. Nijland, of Utrecht, on April 5, in λ 289° Lat. + 38° (*Ast. Nach.* 3488). It was not definitely recorded after May 23, having dispersed itself along a dusky belt.

2. Ten observations were obtained. The spot gradually became faint, and could not be seen at the middle of July. The Rev. T. E. R. Phillips obtained the place of this object on March 21 as λ 265°·5, and March 28 λ 267°·7. Dr. Nijland saw it on April 5 and found it in λ 272°, Lat. + 31°. This object, and the preceding, are shown on a planisphere of *Jupiter* (opposition of 1898) by Signor J. Comas Solà, in *Ast. Nach.* 3,519. He, however, depicts the markings as having a more strikingly beaded or knotted aspect than was observed here.

3. Nine observations. Spot apparently first seen by Brenner on January 20 in λ 144°·5 (*Ast. Nach.* 3476).

4 and 5. These spots were recorded by Fauth as early as 1897 Nov. 25 in λ 305° and 360° (*Ast. Nach.* 3488). I obtained seven observations of No. 4 and seventeen of No. 5. The former was much the smaller of the pair, and could not be seen at all on nights of bad definition.

6. This object was extremely faint, and its elliptical contour usually quite indeterminate. It would often entirely escape notice but for the depression in the S. equatorial belt which guides the eye to its position. The southern boundary of the spot was fringed with dark material, apparently by coalescence with the N. side of the S. temperate dusky belt.

7. Six observations. This marking was in conjunction with the red spot on about March 23.

8. Only three observations were obtained. Conjunction with the red spot occurred on May 10, and it was very bright at about this time with a luminous trail running some distance to S.E.

9 and 10. These showed a period 2^s less than Nos. 7 and 8, but the difference may have arisen either from errors of observation or from a real inconsistency in the rate of motion of the various objects.

11, 12, 13, and 14. Eight observations were obtained of No. 14, but very few of the others. Reliable transits could only be secured when the definition was very good. Early in July No. 14 appeared to have lost its definite character and to have distended itself along a dusky belt on its southern borders. No. 13 appears to have been first seen by the Rev. T. E. R. Phillips at Yeovil on March 23, and for several months it remained a remarkably definite object.

Rotation Periods of Equatorial Spots on Jupiter, 1898.

No.	Spot.	Mean Longitude of Spot.	Mean Date.	Whole Period of Observation.						Length of Interval.			Rotations.	Period of Rotation.			No.
					h	m		h	m	d	h	m		h	m	s	
1	D	0°·1	July 9	June 19,	7	50	July 30,	8	11	41	0	21	100	9	50	28·9	1
2	W	18·5	June 11	May 18,	8	39	July 5,	8	9	47	23	30	117	9	50	26·1	2
3	D	29·2	June 11	May 18,	8	49	July 5,	8	34	47	23	45	117	9	50	33·2	3
4	D	62·2	May 13	Mar. 22,	10	15	July 5,	9	2	104	22	47	256	9	50	19·5	4
5	W	73·0	May 24	April 7,	10	14	July 10,	7	30	93	21	16	229	9	50	19·6	5
6	D	87·3	May 27	April 7,	10	31	July 17,	7	33	100	21	2	246	9	50	24·7	6
7	D	120·4	May 27	April 7,	11	26	July 17,	8	17	100	20	51	246	9	50	24·4	7
8	W	143·0	May 30	April 12,	10	4	July 17,	8	58	95	22	54	234	9	50	26·1	8
9	D	154·1	May 23	April 1,	8	36	July 15,	8	8	104	23	32	256	9	50	28·0	9
10	W	208·8	April 28	April 15,	8	39	May 12,	10	8	27	1	29	66	9	50	27·5	10
11	D	207·3	May 29	April 15,	8	54	July 13,	8	6	88	23	12	217	9	50	17·9	11
12	W	212·8	June 3	April 24,	9	26	July 13,	8	22	79	22	56	195	9	50	22·9	12
13	D	221·1	June 12	May 12,	10	34	July 13,	8	43	61	22	9	151	9	50	26·6	13
14	D	236·9	May 25	April 24,	10	0	June 25,	8	0	61	22	0	151	9	50	25·2	14
15	W	260·6	May 15	April 4,	8	41	June 25,	8	26	81	23	45	200	9	50	19·5	15
16	D	271·5	May 8	Mar. 14,	11	6	July 2,	8	5	109	20	59	268	9	50	20·7	16
17	W	280·0	June 3	May 6,	8	40	July 2,	8	26	56	23	46	139	9	50	20·2	17
18	W	295·9	June 15	May 15,	9	38	July 16,	7	33	61	22	55	151	9	50	20·6	18
19	D	300·5	May 8	Mar. 14,	12	5	July 2,	8	41	109	20	36	268	9	50	16·9	19
20	D	313·7	June 26	June 7,	9	11	July 16,	8	9	38	22	58	95	9	50	24·2	20
21	W	339·5	May 23	April 16,	8	9	June 30,	8	46	75	0	37	183	9	50	19·6	21
22	D	354·9	May 14	April 16,	8	19	June 12,	8	20	57	0	1	139	9	50	24·6	22
23	W	123·9	June 15	May 14,	9	7	July 17,	8	30	63	23	23	156	9	50	26·8	23

In the second column "D" means Dark spot, "W" White spot.

Notes.

1. Five observations. The spot was very dark and distinct, and coincided in position (and very nearly in rate of motion) with that of the zero meridian of system I.

2. Five observations. Spot fairly conspicuous, and moving at nearly same rate as preceding.

3. Five observations. This object apparently gave the longest period of all the equatorial spots, but it was only followed during forty-eight days, which is hardly long enough for exact results.

4. Nine observations. A well-observed object and one of the most definite of its class.

5. Fourteen observations. In June and July this spot became remarkably brilliant, and was certainly more conspicuous than any other marking of similar character near the equator.

6. Eleven observations. Spot well defined, and its identity on different nights satisfactorily assured.

7. Very few observations were made, but the period derived is in good agreement with Nos. 6 and 8.

8 and 9. Seven and eleven observations. These spots, like Nos. 4 and 5, were of very pronounced type and observed sufficiently often to render identification quite certain. They moved slowly as compared with many other of the markings in the same latitude.

10. Only three observations were made, but there is little question that the same object was seen on each occasion.

11. Six observations. This object moved much faster than the foregoing, and apparently passed over it in May, but there is some doubt as to its identity.

12, 13, and 14. Few observations were obtained, though the objects were fairly conspicuous.

15 and 16. Nine and eleven observations. A well-defined pair of spots, of which an adequate number of transits were secured. They moved at nearly the same rate as the equally well observed pair of spots Nos. 4 and 5, but much swifter than Nos. 8 and 9.

17 and 18. Three and five observations. This pair apparently rotated with a velocity uniform with the preceding. They were, however, insufficiently observed, though there seems no reason to question their identification.

19. Six observations. This spot moved very rapidly, and at an irregular rate. Its velocity appears to have been greatest between May 5 and June 7.

20. Five observations. This object apparently moved much slower than the dark spot preceding it or the white spot which followed it.

21 and 22. Four observations were obtained of these objects. The former was very brilliant at times, and occasionally showed itself in the division between the N. and S. sides of the great S. equatorial belt. Its variations of aspect were remarkable and occurred at very short intervals.

23. This spot was recorded on only a few occasions, but it occupied a special position, breaking into the N. equatorial belt. Its rate of motion, being generally consistent with that of the other spots situated on the N. side of the great S. belt, sufficiently proves that the same current prevailed over a considerable zone in the equatorial region of the planet.

The Great Red Spot on Jupiter. By W. F. Denning.

In *Nature* for 1898 August 4 I made some general comments on the associations and rate of motion of this remarkably durable object. Having been further examining the evidence bearing on the early history of the spot, it may be interesting to refer to some of the descriptions of this object in and since 1869, and then to give a table of the varying rotation period it has exhibited during 29 years. I have grouped the observations into periods of about three years, and have selected what appeared to be the most accurate. Though the times of transit had, in several cases, to be estimated from sketches they are believed to be fairly good, as they were carefully checked by other observations made at nearly the same period. Everything lends countenance to the view that the large brick-red spot detected by Russell, Pritchett, and Dennett in 1878 July, and by Tempel, Niesten, and others in the following month, was identical with the object described and figured by Gledhill in 1869 November 14 to 1870 March 29, and on 1871 December 1; by Mayer in 1870 January 5; by Knobel, Birmingham, Pratt, Terby, and Browning in the early months of 1872; by Lord Rosse and Dr. Copeland, 1872 December 31 to 1873 April 10; by Russell and Bredichin in the summer of 1876; and by other observers at various times. True the spot was not continuously visible (or, if so, must have curiously eluded notice), and before 1878 it appears to have been much involved in the brighter material floating in the upper regions of the Jovian atmosphere. But the latitude of the spot, the general size and form of it, the rate of its rotation period, its colour, and the peculiar shouldering of the S.S.* equatorial belt, S. of its preceding and following ends, are all very significant features, and leave no reason to doubt that Gledhill's ellipse, first seen in 1869 November 14, was really the forerunner of the red spot, then perhaps in an incipient stage, and certainly not nearly so well developed as when Lord Rosse and Dr. Copeland rediscovered and followed it, on the last day of 1872 and during the early months of 1873, with the 6-foot reflector at Parsonstown.

1869 November 14 to 1870 March 29. The great southern ellipse was a fine object, and easily seen every clear night. It lay between the S.S. equatorial belt and the S. temperate belt. Its eastern end was the darkest part of it. It was followed up to 1870 March 29, and its transits or approximate positions relatively to the central meridian were noted on twenty-two nights. J. Gledhill (9½-inch refractor), *Astronomical Register*, vol. viii. p. 81, &c.

1870 January 5. "A great elliptical ring observed in the

* This term is adopted for brevity to distinguish the dark belt forming the southern side of the southern equatorial double belt.

planet's S. hemisphere and just S. of the equatorial belt. Its major axis to the minor axis is in its present projection as 1 to 1·51." It was about central at $8^h = 13^h\ 30^m$ G.M.T. A. M. Mayer (6-inch refractor), *Franklin Institute Journal*, 1870 February 7, and *Astronomical Register*, vol. viii. p. 169.

1871 December 1, $11^h\ 30^m$. S. of the S.S. equatorial belt, and near the W. edge of the disc, was a very large dark spot, and to the E. of this object lay the ellipse. Within it was seen a short, slightly curved dark line. A pretty dark band was in contact with the upper edge of the ellipse. A rough measure gave 15″ as the length of the longer diameter of this curious object. J. Gledhill ($9\frac{1}{3}$-inch refractor), *Astronomical Register*, vol. x. p. 11.

1872 January 5, 15^h; January 6, 10^h; and on February 2 and April 11, 16, and 28. A notable slanting streak was observed and drawn in the S. hemisphere; and following it was a well-defined elongated spot or preceding side of a belt lying S. of the great S. equatorial belt. E. B. Knobel ($8\frac{1}{2}$-inch reflector), *English Mechanic*, 1872 September 13.

*1872 January 6, 10^h to $10^h\ 45^m$. On the eastern part of the S. white zone, outlying the dark equatorial belt and just coming into view, was a dusky marking, its western end having an oval outline. H. Pratt ($8\frac{1}{2}$-inch reflector), *Astronomical Register*, vol. x. p. 43.

*1872 January 11 and 13. A striking feature is the belt-like streak which descends from the S., crossing the truncated end of the S.S. equatorial belt at a sharp angle, and reaching down to the S. equatorial belt. A large oval spot follows the slant belt. J. Birmingham ($4\frac{1}{2}$-inch refractor), *Astronomical Register*, vol. x. p. 42.

1872 February 2, 7^h. The sloping band is well seen, and to the east there is a dark and very broad cloud-like mass. J. Gledhill ($9\frac{1}{3}$-inch refractor), *Astronomical Register*, vol. x. p. 68.

1872 February 2, $7^h\ 46^m$. The S. temperate belt dips to N., and following it in about same latitude there is a renewal of the belt in an intensified form. F. Terby ($3\frac{1}{2}$-inch refractor), *Bulletin de l'Acad. R. de Belgique*, vol. xxxiv. Nos. 9 and 10, 1872.

1872 March 17. The slant streak now appears to extend to the dark region about the S. pole. In the angular space between it and the S.S. equatorial belt, and reaching

* Two well-executed sketches of the appearances referred to by Birmingham and Pratt may be seen in *Astronomical Register*, 1872 February. The oval spot presents a very striking resemblance to the red spot of later years. It is to be regretted that Mr. Birmingham did not give the exact times of his observations on Jan. 11, 13, or March 17.

quite across, is a large black spot, and under the spot a bright gap seems cut out of the S.S. equatorial belt. J. Birmingham ($4\frac{1}{2}$-inch refractor), *Astronomical Register*, vol. x. p. 94.

*1872 May 5, 9^h 15^m. A coloured sketch of *Jupiter* at this time shows a white slanting band as about central, while following it is a large dark mass. J. Browning (12-inch reflector), *Monthly Notices*, vol. xxxii. p. 322.

1872 December 31 to 1873 April 10. Of all the features presented to our view during the opposition of 1873 probably the most remarkable was the great break in the southern side of the equatorial belt in long. 260°. . . . Following and filling up this break was a brick-red area that was seen most fully on February 6. . . . The red region may extend over some 30° of longitude, reaching from 250° to 280°; its following end was well seen on March 22. The red area was also seen on 1872 December 31, 1873 January 17 and 22, February 8, March 7, and April 10. Lord Rosse and Dr. Copeland (6-foot reflector), *Monthly Notices*, vol. xxxiv. p. 243.

1873 April 20 and May 11. Two sketches of *Jupiter* exhibit the dip in the S.S. equatorial belt and a dusky mark coming into view on the E. limb. E. B. Knobel ($8\frac{1}{2}$-inch reflector). *Monthly Notices*, vol. xxxiii. p. 476.

1876 June 2, 0^h 35^m G.M.T. The red spot was frequently seen in 1876, and many drawings of it were made at the Sydney Observatory. The distance from the S. pole of *Jupiter* to the dark belt on the N. border of the spot was $15''\cdot54$, and in 1880 the same space was measured as $15''\cdot94$, so no change occurred in the latitude. In 1876 the *p* end of the spot was round and the *f* end pointed, while in 1873, according to Rosse and Copeland's drawings, the *p* end was pointed and the *f* end round. A sketch of the planet on June 2 at Sydney represents the red spot just entered on east limb. The spot was first seen separated from the belts on 1878 July 8; it was then a difficult object to see, but its form and dimensions were similar to that observed in 1876, and the observer was

* The objects depicted by Browning are identical with those alluded to by Knobel, Birmingham, Pratt, Gledhill, and Terby in the previous winter months.

The slanting streak seems to have almost monopolised the attention of observers at this period, while the dark oval mass following it was not much regarded, though really of far greater significance, for it appears to have been undoubtedly the forerunner of the red spot.

The curved dark line seen in the interior of the ellipse by Mr. Gledhill on 1871 December 1 seems to have been preparatory to the filling up of that object with dark material. When it was observed by Knobel on 1872 January 5 and 6 and February 2, by Pratt on January 6, by Birmingham on January 11 and 13, and by Gledhill on February 2 it simply appeared as a dark elliptical mass.

not long in recognising it as an old friend that he had frequently seen. H. C. Russell (11½-inch refractor), *Proceedings of the Royal Society of New South Wales*, vol. xiv. pp. 63–75.

1876 June 20, $7^h\ 30^m$ G.M.T. The spot was drawn just passing off the west limb. It was a dark and definite object with distinctly oval outline. T. Bredichin, *Annales de l'Observatoire de Moscou*, vol. iii. 1877.

Great Red Spot on Jupiter. Rotation Period 1869 *Nov.* 14 *to* 1898 *July* 30.

Observers.	Dates of the Observations.			Interval.			Rotations.	Corrected Rotation Period.			Daily Rate.
		h	m	d	h	m		h	m	s	°
J. Gledhill	1869 Nov. 14	10	50								
				1,209	1	10	2,923	9	55	34·4	870·42
Lord Rosse and Dr. Copeland	1873 Mar. 7	12	0								
				1,182	13	20	2,859	9	55	34·1	870·43
H. C. Russell	1876 June 2	1	20								
				852	11	9	2,061	9	55	33·4	870·45
L. Trouvelot	1878 Oct. 2	12	29								
				725	22	29	1,755	9	55	34·2	870·43
F. C. Dennett, W. F. Denning	* 1880 Sept. 27	10	58								
				1,164	1	43	2,814	9	55	37·3	870·35
W. F. Denning	1883 Dec. 5	12	41								
				1,108	6	44	2,679	9	55	39·6	870·30
" "	1886 Dec. 17	19	25								
				1,074	8	29	2,597	9	55	40·2	870·28
" "	1889 Nov. 26	3	54								
				1,174	2	21	2,838	9	55	40·7	870·27
" "	1893 Feb. 12	6	15								
				1,093	0	34	2,642	9	55	41·0	870·26
" "	1896 Feb. 10	6	49								
				901	1	40	2,178	9	55	41·7	870·24
" "	1898 July 30	8	29								
J. Gledhill	1869 Nov. 14	10	50								
				10,484	21	39	25,346	9	55	37·8	870·34
W. F. Denning.	1898 July 30	8	29								

By selecting other observations in lieu of those utilised in the preceding table, it will be found that the periods deduced from them will be in very fair agreement. Thus, comparing an observation by A. M. Mayer on 1870 January 5, $13^h\ 30^m$, with one by T. Bredichin on 1876 June 20, 6^h, I find the mean period $9^h\ 55^m\ 34^s{\cdot}2$ (5,700 rotations). Bredichin's observation, when combined with one by F. C. Dennett, 1878 September 28, $9^h\ 24^m$, gives a mean period of $9^h\ 55^m\ 33^s{\cdot}8$. Other observations sufficiently prove that previously to the year 1878 the rate of motion of the spot was slightly increasing, but that a retardation set in afterwards. This retardation was very marked in the years 1880, 1881, 1882, and 1883. During this period the annual increase in the rotation period of the object amounted to one second, while during the 14 years from 1884 to the present time

* This is a mean of the estimated times of the same transit taken by two observers. In subsequent years the observations are those made at Bristol.

the average yearly increase has been only 0·2 second or one-fifth of a second.

A few of the objects offering a suggestive resemblance to the red spot, which were figured by observers in 1872 and other years, are certainly not to be identified with the latter. For instance, the dark oval marking drawn by Terby * on 1872 January 3 on the S.S. equatorial belt, and by Corder † in a similar position on 1872 March 13 and April 18, relate to one and the same formation, but it preceded the red spot by as nearly as possible three hours. Elliptical markings occasionally appear in the planet's S. hemisphere which are of more temporary character than, and probably somewhat different in nature to, the red spot. In 1885 a conspicuous red marking, known as the 'new red spot,' was seen on the S.S. equatorial belt, but it did not long remain visible.

In conclusion I give the annual rates of rotation exhibited by the spot. This table is only intended to show the general changes that have occurred; doubtless there have been well-marked minor variations causing a longitudinal oscillation of the object at comparatively short intervals. These, however, could only be satisfactorily traced by comparing a large number of very accurately observed transits. Mr. Marth had contemplated investigating the movement of the spot since 1879, but I fear the work was not completed at the time of his lamented decease.

Rotation Period in Successive Years of the Great Red Spot on Jupiter.

	h m 9 55+ s	Comparisons with other Observers.		s	
1869	34·5				
1870	34·4				
1871	34·4				
1872	34·3				
1873	34·3	30s·6	1872 Dec. 31–1873 April 10, Rosse and Copeland		
1874	34·2				
1875	34·0				
1876	33·7				
1877	33·4				
1878	33·7				
1879	34·1	34·0	1879, G. W. Hough	34·1	1878–80, Marth
		33·9	1879 July–Dec., H. Pratt	34·4	1879-80, Schmidt
1880	35·2	35·1	1880, H. Sternberg	35·3	1879-81, Schmidt.
		35·4	1880, G. W. Hough		

* *Bulletin de l'Académie Royale de Belgique*, vol. xxxiv. Nos. 9 and 10, 1872.
† *Observatory*, 1882 January.

	h m 9 55 + s	Comparisons with other Observers.	
1881	36·3	36·1 1881, H. Sternberg	
		36·4 1881, G. W. Hough	
1882	37·3	37·3 1882, H. Sternberg	
1883	38·2	38·1 1883, H. Sternberg	
		38·4 1883, G. W. Hough	
1884	39·0	39·2 1884, H. Sternberg	1883–5
		38·5 1883 Sept. 12–1884 June 11, G. W. Hough	38s·9, Marth
1885	39·6	40·1 1885, H. Sternberg	
		40·4 1884 Sept. 25–1885 June 29, G. W. Hough	
1886	39·9	40·1 1886, H. Sternberg	
		40·7 1886, C. A. Young	
		39·9 1886, G. W. Hough	
1887	40·1	40·6 1887, H. Sternberg	
		40·5 1887, A. S. Williams	
1888	40·2		
1889	40·4		
1890	40·5	39·8 1890 July–December, G. W. Hough	
1891	40·6	40·7 1890 December 8–1892 January, G. W. Hough	
1892	40·8		
1893	40·9		
1894	41·0	40·9 1893 December 20–1895 January 24, G. W. Hough	
1895	41·1		
1896	41·3	41·4 1896, G. W. Hough	
1897	41·6	42·4 1897 March–May, A. S. Williams	
1898	41·9	42·4 1898 March–June, T. E. R. Phillips	

Bristol: 1898 *September* 15.

Observations of Jupiter and Jupiter's Satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the Opposition 1897–8. By Joseph Gledhill.

This paper comprises the following subdivisions :—

1. A description of the principal features seen on the disc of *Jupiter*.
2. Transits of red spot, dark spots, &c.
3. Measures of the position of the principal dark belts and spots.
4. Measures of the bright zones, dark spots, &c.
5. Observations of phenomena of *Jupiter's* satellites.

6. Notes on certain phenomena presented by *Jupiter's* satellites and their shadows during transit across the disc.

The observations were made with the 9-inch Cooke Equatorial Refractor (object glass, one of the new triple lenses by Messrs. T. Cooke and Sons, York) and a Simms parallel-wire micrometer. The negative eyepieces used were of powers 150 and 240; the measures were made with a power of 200. The planet was examined on every fine night from October 1897 to July 1898. On no occasion could a power higher than 240 be used. Some idea of the exceptionally bad observing conditions which prevailed during the opposition may be formed from the following statement: *a*, number of nights continuously clear throughout; *b*, good observing nights; *c*, fair; *d*, bad; *e*, sunless days.

	a	*b*	*c*	*d*	*e*
1897 October	5	1	2	5	13
November	2	0	0	6	20
December	2	0	4	12	8
1898 January	0	0	1	4	15
February	4	0	4	9	8
March	6	4	4	10	4
April	2	0	3	4	6
May	0	4	2	6	6
June	3	0	5	6	4

A Description of the Principal Belts, &c., seen on the Disc of Jupiter during the Opposition, 1897–8. For terminology of Bands, &c., see *Measures of the Position, &c.*

Band 0 (*the S.S. Temperate Band*).

This somewhat faint grey band near the S. pole was not easily seen in all longitudes. Even when definition was good it was sometimes a difficult feature. In certain longitudes, however, it was easily seen as a broad grey band, as the following notes will show. The longitudes are from Mr. Crommelin's Ephemeris system II.

1898 March 8, $11\frac{1}{2}^h$, $\lambda=106°$ (*i.e.* longitude of the central meridian of the apparent disc); faint and narrow. March 10, 11^h, $\lambda=28°$; the band is faint; it is about as far S. of 1 as 1 is S. of 2. March 14, 11^h, $\lambda=240°$; well seen. March 19, 11^h, $\lambda=300°$; well seen. March 20, 9^h, $\lambda=20°$; well seen; $10\frac{1}{2}^h$, $\lambda=90°$; faint. March 21, 11^h, $\lambda=243°$; not seen, yet 1 is a very easy feature. March 23, 9^h, $\lambda=111°$; well seen; 10^h to 11^h, $\lambda=148°$–$184°$; not seen as a belt distinctly separated from the polar shading to the S. March 30, 11^h, $\lambda=157°$; not seen. April 5, 11^h and 12^h, $\lambda=339°$ and $16°$; well seen. May 6, 10^h,

$\lambda=283°$; easy, a distinct band all the way across the disc. At 9^h, $\lambda=247°$; a wider and darker portion of the band had reached the central meridian; and a large dark spot on it was central about $10^h\ 24^m$, $\lambda=298°$. May 11, 7^h, well seen; $\lambda=206°$. May 16, $8\frac{1}{2}^h$, well seen, $\lambda=291°$. May 18, $10^h\ 10^m$, the dark spot was central, $\lambda=292°$. At this time the band was as broad as 1, and more distant from 1 than 1 from 2. May 28, $8^h\ 20^m$, $\lambda=288°$; faint. June 28, $8\frac{1}{2}^h$ to 9^h, $\lambda=269°$ to $287°$; well seen, a little darker and broader than 1.

So that it appears to have been well seen in longitudes of central meridian 16° to 28°, 200° to 250°, and 270° to 340°; and very faint in about 90° to 110°, and 140° to 180°.

Band 1 (*the S. Temperate Band*).

This band was always visible, sometimes quite narrow and faint, at others quite a prominent feature. Its general appearance was that of a strap-like, grey band; but in some longitudes its S. edge was a sinuous line.

1897 October 21, 6 A.M., well seen all across the disc. 1898 February 16, $12\frac{1}{2}^h$, $\lambda=15°$; faint. February 18, 11^h, $\lambda=261°$; faint. February 21, 10^h to 12^h, $\lambda=316°$ to $28°$; very faint. February 22, 12^h, $\lambda=180°$, faint; and on the 24th at 11^h, $\lambda=83°$, and the 27th at 12^h, $\lambda=211°$. March 2, 10^h, $\lambda=230°$; well seen. March 3, 12^h, $\lambda=92°$; faint; and on the 6th at 10^h, $\lambda=110°$; but at 12^h it began to widen a little to the east of the central meridian, say when $\lambda=184°$. March 7, 12^h, $\lambda=334°$; well seen; also at 11^h on the 10th, $\lambda=29°$. March 12, 10^h faint; $\lambda=293°$. March 14, 10^h, $\lambda=234°$; well seen, it ranks next to 2, 3, and 4 in prominence. March 19, 11^h, $\lambda=303°$; well seen. March 20, 9^h, $\lambda=21°$; well seen; so also on the 21st at 10^h, $\lambda=207°$. Passing over a good many similar observations the following may be given as times when the band was very faint: February 21, as above; also May 12, 7^h and 8^h, $\lambda=356°$ and $33°$, very faint and narrow; so also on May 18, 9^h, $\lambda=250°$. The sinuous appearance of the S. edge was well seen on May 14, at 8°, $\lambda=315°$ and the band was faint. On April 12, 7^h to 10^h, $\lambda=167°$ to $276°$; the band was well seen, and at 8^h, $\lambda=203°$, it was nearly as wide as zone *b*. The sudden widening of the band was seen on March 6 as above, and also on May 3, May 6, May 8, May 12, and June 27.

Band 2 (*the S. Component of the S. Equatorial Belt*).

There has probably been very little change in the appearance of this band since the last opposition. The two shoulders are still very marked features in it, and so are its disappearance between the shoulders and its sudden change of depth of tone in a certain longitude. The following notes give all the most noticeable observations:—

It was seen narrower than 3 on February 8, 13^h, $\lambda=269°$, and not so dark; also on February 16, 12^h, March 6, 10^h, March 30, 11^h; as dark and broad as 3 on March 20, 11^h, March 23, 9^h, May 15, 8^h, May 16, 7^h, May 18, $8\frac{1}{2}^h$. On March 7, 12^h, it appeared broken up into dark portions, or had dark forms on it. Its S. edge was irregular in outline on March 20, 11^h, and on March 23, at $8\frac{1}{2}^h$. The darkest and most striking portion of the band is at the *f* shoulder; and at this place too a kind of tuft or wisp was often seen projecting into the bright zone to the south. The other noteworthy feature is its sudden change in depth of tone and in width; when this point was seen near the W. limb (*i.e.* passing off the disc) it was known that the *p* and *f* shoulders would soon be seen at the E. limb. When the red spot was on the central meridian the faint and narrower portion of 2 extended quite to the *p* limb.

Band 3 (the N. Component of the S. Equatorial Belt).

Of all the dark bands seen on the disc of *Jupiter* during this opposition this has been in many respects the most interesting. Its S. edge has often presented a fairly uniform and undisturbed outline; it has been dark and broad in all longitudes—indeed, the darkest and broadest band on the disc—and the dark oblong spots on, or detached portions of, this band, the bright gaps between them, the apparent shift of some portions to a more northern latitude, and the draggling down (to N.) of cloudy matter or form into the central zone, have formed very interesting objects of observation. A few notes selected from a large number will show the general character of these phenomena:—

1897 October 21, 6 A.M., the band was broken up into detached dark portions. 1898 February 8, some of the dark forms project into the central zone; so also on February 16 and February 18. On February 21, 13^h, three dark elongated portions of the band lay under and in contact with the N. edge of the band. February 22, 11^h to 12^h, a gap or break was seen in 3, followed by a dark spot on it; and just to the east of the spot the band became darker all the way to the *f* limb of the planet. Bright gaps and dark spots, or detached short portions of the band, were also seen on February 23, 11^h; February 24, 11^h and $12\frac{1}{2}^h$; February 27, 12^h; March 2, 13^h, and many other nights. Sometimes, as on March 6, 10^h, the whole band was a series of six or more dark portions with bright spaces between them. These detached oblong portions were occasionally seen slightly inclined to the general direction of the band, as on March 10 at 11^h. There was a dark spot or protuberance just under (to N. of) the *p* shoulder on June 12, $8\frac{1}{2}^h$, and it projected into the central zone. This was often seen. A similar form was seen just under, or a trifle behind (to E.), the *f* shoulder, *e.g.* May 14, $7\frac{1}{2}^h$. On May 16, $8\frac{1}{2}^h$, the whole band consisted of three detached portions.

Bands 2 and 3 lay very close together, leaving but a very narrow bright zone between them, except when 2 became suddenly pale, grey, and narrower, *i.e.* a few hours before the red spot reached the central meridian.

Band 4 (*the N. Equatorial Belt*).

This prominent band (double during the opposition of 1896–7, but single during that of 1897–8) was quite as much broken up as band 3. Its south edge was in most longitudes ill defined. The following notes will give a good idea of the phenomena presented by this band during a rotation of the planet:—

1897 October 21, 6 A.M., as dark and broad as 3 and more broken up, the S. edge being a series of projecting forms, the N. edge a smooth line. 1898 February 18, 11^h, as dark as 2 or 3. February 24, 11^h, seems double. February 27, 12^h, a fairly uniform band. March 6, 10^h, not nearly so broad as 3; so also at 12^h. March 12, 10^h, nearly as dark and broad as 3. March 20, 9^h, as wide and dark as 3, and broken up. March 21, 13^h, very broad and dark. March 24, 9^h, as on March 20; same on March 30, 11^h. April 4, $9\frac{1}{2}^h$, narrow and dark. April 12, 7^h, as on February 18. May 4, 10^h, narrow and dark; N. edge sharp; S. edge indefinite. May 12, 8^h, narrow; 11^h, not so dark as 3. It was dark and broad on May 15, $7\frac{1}{2}^h$; May 16, 7^h; and May 27, 10^h; narrow on June 22, $10\frac{1}{2}^h$.

Band 5 (*the N. Temperate Band*).

This band was nearly always faint, sometimes very faint, and perhaps altogether absent in some longitudes. Its width was not the same in all longitudes. To give its appearance as 'faint,' 'very faint,' 'much fainter than 1' on the thirty to forty nights on which it was examined would serve no useful purpose here. 1898 February 22, 11^h, an elongated dark spot was seen on band 5, a faint narrow band; this faint band was seen again at 10^h, March 6. March 10, 11^h, the band is very faint, and is a little more distant from 4 than 1 is from 2; it is a mere line. March 23, 9^h, distance of 5 from 4 equals that of 5 from 6; at $9\frac{1}{2}$, distance of 5 from 6 is less than that of 4 to 5. At 10^h and 11^h band 5 was broad and well seen. June 27, 8^h, in the same longitude as the *f* end of the dark spot *a*, but a little to the N., appeared a similar narrow spot, probably forming part of band 5, which was seen as a narrow band to the east, but not to the west, of the spot. This was seen again on June 27, about 8^h, and on a later date. With good definition it would, no doubt, have been seen every time spot *a* came near the central meridian.

Band 6 (*the N.N. Temperate Band*).

The following notes contain a summary of all that was seen of this faint band: 1898 March 10, 11^h, it was darker and broader

than 1, and much darker and broader than 5. March 14, 10^h, darker than 5: its darkest part was on the central meridian, about $10^h 45^m$. The band was very faint on 19 March at 11^h, and on the 20th at 9^h; but at $10\frac{1}{2}^h$ on the latter day it was broad and dark, as on 10 March. It was faint or very faint on March 30, 11^h, April 4, $9\frac{1}{2}^h$, May 3, 11^h, and May 12, 8^h; on May 6, 10^h, it was seen as a mere grey line. At $8\frac{1}{4}^h$ on June 22 the *p* end of a darker portion of the band was on the central meridian; this darker eastern portion was as broad and dark as 1.

The Bright Zones b (S. Tropical) and d (N. Tropical).

These two zones were always the brightest portions of the disc, and *b* was perhaps always brighter than *d* on the more than forty nights of observation.

The Central Zone (Equatorial Zone).

This zone was always of a warm yellow or ruddy colour, and was often mottled, but it was found impossible to see clearly the forms of the markings. In its northern part, near the dark band 4, a faint discontinuous band was occasionally seen: *e.g.* on 1898 March 20, at $10\frac{1}{2}^h$, two portions of this band were seen; also at 13^h on February 21, and at $7\frac{1}{2}^h$ on May 14.

The Polar Regions.

During the moments of best definition on good nights the shading in these regions could be seen to consist of fine lines or bands for a considerable part of the distance between 0 and 6 and the poles. The principal facts that appear from the observations are: (1) the region *a* was probably brighter than *e* in all longitudes; (2) the shading in *e* was always (at any rate ofter May 3) much less distinct than that in *a*: this difference was quite marked on several occasions. When the lines in *a* were well seen all was hazy and indistinct in *e*. (3) The region *a* was occasionally bluish, while that of *e* was yellowish.

The following are the observations:—1898 February 20, March 10, 12^h, March 31, 9^h to 10^h, May 3, $8\frac{1}{2}^h$, May 4, 7^h, May 8, 9^h, May 16, 7^h, May 18, 7^h, the shading in *a* was brighter than that in *e*. On March 12, 10^h, March 20, 9^h, March 21, 9^h, *a* was much brighter than *e*. On May 3, $8\frac{1}{2}^h$, the S. edge of *e* was dark or formed by a narrow dark band. On May 4, 10^h, the shading in *a* was seen broken up into fine grey bands, while that in *e* was quite indistinct. May 11, 7^h, *e* had a dark S. edge. May 12, 8^h, *a* distinct, *e* indistinct or cloudy; but at $10\frac{1}{2}^h$ both were equally definite and bright. On May 6 at 8^h *a* was for once darker than *e*. It is probable that the low altitude of the planet would account for some differences of colour, such as, for example, that contained in the observation on May 6 at $9\frac{1}{2}^h$,

"the S. polar region is bright and white, while all to the N. of band 4 is yellowish."

From the foregoing notes it will be seen that the salient features visible on the disc of Jupiter during this opposition were as follows: the double dark band 2, 3 just S. of the equator; the single dark band 4 just N. of the equator, the coloured central zone, and the grey band 1. On fine nights, and almost in all longitudes, the faint bands 0, 5, and 6 could be seen; and in certain longitudes portions of a narrow band were seen in the northern part of the central zone. Of course, too, on fine nights the irregularities—gaps, protuberances, &c.—on bands 2, 3, and 4, in certain longitudes, were also very striking features. Lastly, three dark grey elongated spots were easy objects on good nights. Of bright circular spots few were seen, owing partly, no doubt, to the low altitude of the planet and the marked absence of nights of really fine definition. A few small bright circular spots were seen between bands 2 and 3, on the S. edge of band 0, and between bands 4 and 5.

Transits of the Red Spot, the Shoulders, Dark Spots, &c.

The Red Spot.

This object was difficult throughout the opposition. It was distinctly seen on but one or two occasions. The *f* end was often glimpsed. No trace of warm colour was ever seen within its outline. It will be obvious, therefore, that no great accuracy can be claimed for the times of its transit over the central meridian of the apparent disc.

1898.	h m	°	1898.	h m	°
Apr. 5	12 13	24	June 10	6 48	24
8	9 42	23	12	8 25	24
May 4	11 10	25	14	10 3	23
12	7 46	24	17	7 37	26
14	9 24	24	24	8 25	25
28	11 0	25	July 11	7 30	24
31	8 30	25	13	9 10	24

The p Shoulder.

This is not a very definite point: it is the point where the band 2 begins to bend down to band 3.

1898.	h m	°	1898.	h m	°
Apr. 5	11 46	7	May 31	8 0	7
8	9 14	6	June 9	10 25	6
10	10 56	9	12	8 0	9
May 4	10 40	7	14	9 35	6
12	7 20	8	17	7 7	7
14	8 56	7			

The f Shoulder.

1898.	h m	°	1898.	h m	°
Feb. 21	12 20	40	Apr. 8	10 5	37
23	13 55	39	10	11 46	39
Mar. 3	10 33	40	May 4	11 35	37
10	11 15	38	12	8 12	40
12	12 55	39	14	9 50	39
14	14 31	38	31	8 58	42
17	12 3	40	June 10	7 15	41
19	13 40	39	12	8 55	42
20	9 34	41	14	10 30	40
22	11 10	40	17	8 5	42
25	8 24	39	22	7 15	43
Apr. 5	12 35	37	24	8 55	43

Dark Spot a.

This was seen on Feb. 22 for the first time and under very bad atmospheric conditions; it was not nearly so dark as band 4, close to the N. edge of which it lay; it was on a very fine band. This fine band was again seen on March 6 at 10^h. On March 8 the spot was seen to be just out of contact with band 4. It was seen to be broadest and darkest at its western, *i.e.* preceding, end on March 10 at 13^h.

1898.	h m	°	1898.	h m	°
Feb. 22	10 40	130	May 12	10 10	111
Mar. 2	17 14	132	15	7 42	112
6	10 35	132	31	10 46	107
8	12 10	130	June 5	9 52	105
10	13 49	131	10	9 0	105
12	15 27	131	15	8 10	105
15	12 57	132	17	9 45	103
18	10 25	131	22	9 0	106
20	12 2	131	27	8 10	107
23	9 35	133	July 9	7 50	96
25	10 58	132	11	9 25	93
30	10 17	131	16	8 35	93

Dark Spot b.

This was a small faint spot, not in contact with dark band 4, just to N. of it, and about 1″ in length.

1898.	h m	°	1898.	h m	°
Mar. 14	10 55	268	May 6	9 0	247
21	11 38	266	11	8 9	248
24	9 5	265	18	8 50	244
May 3	11 33	249			

Dark Spot c.

This was a long grey spot just to the N. of dark band 4; the length, estimated, on Feb. 23 was about 3″; length to width, about 3 to 1. Its length, measured on March 31, was 4″·7 (reduced to mean distance).

1898.	h m	°	1898.	h m	°
Feb. 23	11 43	319	May 4	8 44	297
Mar. 2	12 25	317	6	10 12	291
7	11 32	317	11	9 15	288
12	10 34	314	16	8 28	290
14	12 9	312	18	10 0	286
17	9 39	313	28	8 20	288
19	11 17	313	June 9	8 15	287
21	12 52	311	14	7 17	283
24	10 24	313	28	8 43	277
31	10 57	306	July 10	8 35	273
Apr. 8	7 30	304	15	7 38	267
12	10 47	304			

Dark Spots on or close to N. Edge of Band 3.

1898.	h m	°	1898.	h m	°
Feb. 21	13 30	83	June 10	9 35	126
22	11 40	167	10	10 18	152
Mar. 2	15 57	86	14	9 35	6
7	12 0	334	15	8 35	120
10	13 42	127	17	9 45	103
12	14 10	85	17	8 47	68

Bright Gaps in Band 3.

1898.	h m	°	1898.	h m	°
May 6	8 5	214	May 11	8 25	257
8	9 40	212	18	8 40	238
11	7 0	206	18	10 35	308

Measures of the Position of the Principal Belts and Spots.

The bands (or belts) and zones will be readily identified with the aid of the terminology used by the *British Astronomical Association*, viz. the S.S. Temperate band (0), the S. Temperate zone, the S. Temperate band (1), the S. Tropical zone (*b*), the S. Equatorial belt (2, 3), the Equatorial zone (*c*), the N. Equatorial belt (4), the N. Tropical zone (*d*), the N. Temperate band (5), the N. Temperate zone, the N.N. Temperate band (6), the

N.N. Temperate zone, the S. Polar Region (*a*), the N. Polar Region (*e*).

The position of a feature of the disc was determined by measures from both limbs (N. and S.), the web through the spot, &c., being made parallel to the belts. The value of one revolution of the micrometer screw is $13''\cdot84$, and one division of the divided head is $0''\cdot138$.

As an illustration of the kind of accordance in the measures on a good night the following extract from the note-book is given :—

1898 March 31, $41''\cdot6$, $42''\cdot2$, $42''\cdot8$, $41''\cdot9$, $41''\cdot9$, $41''\cdot9$, $41''\cdot8$, $42''\cdot8$, $42''\cdot2$, $42''\cdot3$, $42''\cdot4$, $41''\cdot9$. Mean, $42''\cdot14$; mean difference from the mean, $0''\cdot3$.

These are from measures of the positions of belts, zones, and spots, and are the resulting polar diameters of Jupiter. Mr. Crommelin's computed value for mean noon was $42''\cdot1$.

In the following measures of the position of the belts, &c., on the disc of Jupiter no correction has been applied for the jovicentric latitude of the Earth above the equator, but all have been reduced to mean distance $\Delta 5''\cdot20$.

The S.S. Temperate Band (0).

As this band was seldom well seen very few measures of its position were obtained. The last column gives the longitude of the central meridian at the time of observation.

1898.	$''$	$°$
Mar. 14	$-11\cdot6$	240
May 11	$-11\cdot4$	200

e. the measures were made when the longitude of the central meridian of the apparent disc was 240°, &c.

The S. Temperate Band (1).

1898.	$''$	$°$	1898.	$''$	$°$
Mar. 6	$-7\cdot6$	130	Mar. 31	$-8\cdot1$	230
10	$-7\cdot6$	30		$-7\cdot7$	280
14	$-6\cdot1$	240	Apr. 4	$-8\cdot0$	170
19	$-8\cdot8$	300	12	$-8\cdot1$	180
20	$-7\cdot7$	90		$-7\cdot5$	200
21	$-7\cdot7$	210	May 6	$-7\cdot8$	240
23	$-7\cdot7$	150		$-8\cdot4$	180
30	$-7\cdot6$	160	11	$-8\cdot1$	200
	$-7\cdot6$	190			

Means: 1897–8, $-7''\cdot8$; 1896–7, $-8''\cdot2$; 1895–6, $-8''\cdot7$.

The S. Equatorial Belt (2).

This is the S. component of the double band just S. of the equator.

1898.	″	°	1898.	″	°
Mar. 6	−4·0	130	Mar. 22	−4·6	0
10	−4·7	30	23	−4·8	150
14	−4·1	240	31	−4·4	230
19	−5·0	300		−3·9	280
20	−4·0	20		−4·9	320
21	−5·9	210	Apr. 5	−5·0	260

Means: 1897–8, −4″·6; 1896–7, −5″·4; 1895–6, −5″·7.

The measures were made from the middle of the band; those in 1895–6 from the S. edge of the band.

The S. Equatorial Belt (2, 3).

The measures were made from the middle of 2, 3, or from the bright streak between them.

1898.	″	°	1898.	″	°
Mar. 14	−4·1	240	May 6	−3·2	240
31	−3·6	230	11	−3·1	200
Apr. 12	−3·3	200	18	−3·8	200

Means: 1897–8, −3″·5; 1896–7, −3″·4; 1895–6, −3″·9.

The N. Equatorial Belt (4).

(Double in 1896–7; single in 1897–8.)

1898.	″	°	1898.	″	°
Mar. 8	+4·0	90	Mar. 31	+4·6	230
10	4·5	30		3·3	280
14	3·8	240	Apr. 4	3·1	150
19	4·4	300	5	3·3	260
20	3·8	20	12	2·7	220
21	3·4	210	May 6	3·4	200
22	3·8	0		3·6	240
23	4·0	150	11	3·3	200
30	+3·2	190	18	+2·9	180

Means: 1897–8, +3″·6; 1896–7, +4″·1*; 1895–6, +2″·4.

In 1895–6 this belt was "inconspicuous in all longitudes, and was seldom well seen."

* N. edge = 6″·0.

The N. Temperate Band (5).

1898. Mar. 21	+7″·5	210°	1898. Apr. 4	+7″·5	170°
30	6·3	160	12	+7·0	200
	+6·6	190			

Means: 1897–8, +7″·0; 1895–6, −7″·4.

The N.N. Temperate Band (6).

1898. Mar. 14	+10″·1	240°
20	+9·9	90

Mean: +10″·0.

The Equatorial Zone (*c*).

The measures were made from the middle of this zone to the N. and S. poles: difficult and uncertain.

1898. Mar. 30	+0″·6	160°	1898. Apr. 8	+″·6	0°
31	·3	230	12	·6	200
	·3	280	May 11	·7	200
Apr. 4	+·6	150	18	+0·8	200

Means: 1897–8, +0″·6; 1896–7, +0″·3.

The Middle of Zone b.

1898. Mar. 30	−5″·7	160°	1898. Apr. 4	−5″·2	20°
31	5·7	250	12	6·4	200
	5·9	280	May 18	−6·4	180

The mean is −5″·9.

The Middle of Zone d.

1898. Apr. 4	+5″·2	170°

The Dark Spots a, b, c.

1898. Mar. 6	+5″·7	*a*	1898. Mar. 30	+5″·6	*a*
8	5·2	*a*		5·6	*a*
14	5·2	*c*	31	4·3	*c*
19	4·7	*c*		4·8	*c*
20	5·7	*a*		5·1	*c*
21	4·7	*b*	Apr. 12	4·9	*c*
23	5·4	*a*	May 18	+4·5	*b*

Mean: 1897–8, +5″·1.

The three spots were probably not in exactly the same latitude; at any rate the distances of their centres from the N. edge of band 4 were not quite the same.

Measures of the Breadth of Bright Zones and Dark Spots, &c.

The Equatorial Zone (c),

i.e. the width from the N. edge of band 3 to the S. edge of band 4. The last column gives the longitude of the central meridian at the time of observation.

1898.	″	°	1898.	″	°
Mar. 8	4·0	90	Mar. 30	3·7	160
19	3·9	300	31	3·4	230
20	3·5	110	Apr. 8	3·4	0
21	3·2	210	12	3·3	200
23	3·8	110	May 6	4·2	190
30	3·7	160			

Means: 1897–8, 3″·6; 1896–7, 3″·0.

The last column, as before, gives the longitude of the central meridian at the time of observation.

The S. Tropical Zone (b).

1898.	″	°	1898.	″	°
Mar. 21	2·3	240	Mar. 31	1·3	250
23	1·3	110	Apr. 12	1·2	200
30	1·7	150			

Means: 1897–8, 1″·4; 1896–7, 1″·7.

The N. Tropical Zone (d).

1898.	″	°
Mar. 23	1·7	110
May 6	1·8	190

Breadth of 2, 3, the Central Zone c, and 4,

i.e. from the S. edge of band 2 to the N. edge of band 4.

1898.	″	°	1898.	″	°
Mar. 6	9·6	130	Mar. 30	8·2	190
8	9·4	90	31	8·1	230
10	9·1	30	Apr. 4	8·1	150
19	8·3	300	8	8·2	0
20	8·3	20	12	8·0	200
	8·5	110	May 6	7·5	180
21	8·1	210		7·6	200
22	8·2	0		8·0	220
23	8·5	110	11	7·4	200
30	8·2	160			

Means: 1897–8, 8″·3; 1896-7, 10″·9.

Breadth of 2, 3,

i.e. the double *S. equatorial belt* and the narrow bright space between them.

1898.	″	°	1898.	″	°
Mar. 6	3·6	110	Mar. 30	3·3	130
8	4·1	98	31	3·4	230
10	3·3	30	Apr. 4	3·7	140
14	4·1	250	8	3·4	20
19	3·3	300	12	3·3	203
20	3·5	20	May 6	3·8	180
21	3·6	207		3·1	151
23	3·7	120			

Means: 1897–8, 3″·5; 1896–7, 3″·8.

Breadth of the N. Equatorial Belt (4).

This band was double during the opposition 1896–7.

1898.	″	°	1898.	″	°
Mar. 8	1·3	90	Mar. 30	0·9	160
14	1·6	240	31	1·2	230
19	1·4	300	Apr. 8	1·2	320
20	1·2	110	12	1·2	203
21	1·2	210	May 6	1·6	211
23	1·2	110			

Means: 1897–8, 1″·3; 1896–7, 3″·9.

Breadth of the South Temperate Band (1).

1898.	″	°
Mar. 31	1·3	250
May 6	1·6	211

Means: 1897–8, 1″·4; 1896–7, 1″·1.

This was always a difficult band to measure; and along with the measure on March 21 is given the remark, "Width of band 1=about $\frac{1}{3}$ of width of zone *b*." On April 12 the note occurs, "8^h: 1 is nearly as wide as zone *b*;" and on May 12, 7^h to 8^h, "1 is very faint and indistinct and narrow—quite unlike its general appearance;" a wider and darker portion began to approach the central meridian about $11\frac{1}{2}^h$. On March 21, when the longitude of the central meridian was 210°, the measure was 0″·7, very different from that on May 6.

The Dark Spots.

1898. *a.* March 6. Length, 5″; distance of middle of spot from the N. edge of band 4=2″. The spot was about half an hour in passing the central meridian.

1898. *b.* March 14. Length about 1″.
1898. *c.* March 14. Length, $3\frac{1}{3}''$; time taken in passing the central meridian on March 14 and 31, about 20 minutes. A measure of the length on March 19 was 3″.

These were all difficult objects to measure, even on good nights.

Observations of Phenomena of *Jupiter's* Satellites with the 9-inch Cooke Equatorial Refractor.

Day of Obs. 1897.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation. h m s	G.M.T. of *N. Almanac.* h m s
Oct. 20	I. (*a*)	Ec. D.	Fading	17 22	17 23 35
			Just gone	17 23 27	
1898. Feb. 21	II. (*b*)	Ec. D.	Fading	12 22 ·	12 25 27
			Bisected?	12 24 30	
			Just gone	12 25 31	
	I. (*b*)	Ec. D.	Fading?	14 23	14 24 14
			Bisected?	14 24	
			Just gone?	14 25	
23	II. (*c*)	Tr. E.	External contact	11 4 ·	11 3
	I.	Oc. R.	External contact	11 45	11 46
Mar. 2	III. (*d*)	Tr. I.	External contact	10 6	10 10
			Bisection	10 9	
			Internal contact	10 13	
	III.	Tr. E.	Internal contact	12 22	12 33
			Bisection	12 28	
			External contact	12 33	
	III. (*d*)	Sh. E.	Internal contact	10 30	10 38
			Bisection	10 34	
			Just off	10 36 30	
	I. (*e*)	Ec. D.	Fading	10 43	10 45 50
			Bisection	10 45 30	
			Just gone	10 46 0	
	II.	Tr. I.	External contact	10 47 30	10 51
			Bisection	10 49	
			Internal contact	10 52	
	II. (*f*)	Sh. E.	Internal contact	12 14	12 18
			Just off	12 17	
	II.	Tr. E.	Internal contact	13 12	13 19
			Bisection	13 14	
			External contact	13 16	

Day of Obs.		Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	G.M.T. of *N. Almanac.*
1898.					h m s	h m s
Mar.	3	I. (*f*)	Sh. E.	Internal contact	10 12	10 12
		I.	Tr. E.	Internal contact	10 37	10 42
				External contact	10 43	
	10	I.	Sh. E.	Internal contact	12 5	12 6
				Bisected	12 6	
		I.	Tr. E.	External contact	12 27	12 27
	20	III. (*g*)	Oc. D.	External contact	8 57	8 56
May	3	I.	Oc. D.	External contact	8 29	8 29
				Bisection	8 31	
				Just gone	8 32	
		I.	Ec. R.	First seen	11 31 58	11 32 11
				Bisection?	11 33	
				Full?	11 36	
	4	I. (*h*)	Tr. E.	Internal contact	7 59	8 2
				Bisection	8 1	
				External contact	8 3	
		I.	Sh. E.	Internal contact	8 49	8 53
	11	I.	Tr. I.	External contact	7 36	7 35
				Internal contact	7 40	
	12	I.	Ec. R.	First seen	7 55 36	7 55 11
				Full?	7 58	
	14	II. (*i*)	Ec. R.	First seen	8 56 1	8 56 6
	18	I.	Tr. I.	External contact	9 24	9 24
				Bisection	9 27	
				Internal contact	9 29	
		I.	Sh. I. (*j*)	Internal contact	10 30	10 28
June	10	I.	Tr. I. (*j*)	External contact	9 28	9 27
				Internal contact	9 33	
		III.	Tr. I. (*j*)	External contact	10 24	10 23
				Internal contact	10 29	
		I. was on the central meridian about 10^h 33^m				
	17	IV.	Tr. I.	External contact?	9 30	9 45
	28	III. (*k*)	Oc. D.	External contact	8 17 30	8 17
				Bisection	8 20	
				Just gone	8 23	
July	9	Shadow of III. on central meridian about 8^h 30^m				
	11	I. (*l*)	Oc. D.	External contact		8 45

Notes.

(*a*) Planet low; strong twilight. (*b*) Clouds passing. (*c*) Much boiling. (*d*) Very difficult and uncertain, owing to motion and to fact that the ingress occurred near N. pole. (*e*) Clouds passing. (*f*) Much boiling on limb. (*g*) Bad definition. (*h*) Much motion. (*i*) Very bad definition. (*j*) Bad definition. (*k*) Bright sunshine; much motion. (*l*) Much motion.

Powers used 150 and 240.

NOTES ON CERTAIN PHENOMENA PRESENTED BY *Jupiter's* SATELLITES AND THEIR SHADOWS DURING TRANSIT ACROSS THE DISC.

1898 March 2. III. When the shadow of this satellite was approaching the W. limb (egress) it was large, black, and elongated in a direction parallel to the belts. The satellite passed on to the disc about $10^h\ 9^m$; at $10^h\ 50^m$ it was seen as a dusky or grey spot; became invisible about $10^h\ 20^m$; and reappeared as a bright object about $12^h\ 10^m$. It moved along the S. edge of the N. polar shading. Sat. II. was invisible at $11^h\ 2^m$.

March 3. I. in transit; it was invisible at 9^h, and so remained till $10^h\ 20^m$.

March 10. I. in transit. It was invisible at $10\frac{1}{2}^h$, and so remained till $12\frac{1}{4}^h$.

May 11. I. in transit. The satellite moved along the bright zone *d*, *i.e.* the N. tropical zone. It was a bright object on the disc at $7^h\ 45^m$; then faint; invisible at 8^h; reappeared at $8^h\ 10^m$ as a very faint grey spot; much darker at $8\frac{1}{2}^h$; as black as a shadow at 9^h, and so remained till after 10^h, when cloud and rain stopped further observation. It was on the central meridian about $9^h\ 27^m$.

May 18. I. in transit, moving along the bright zone *d*. Ingress about $9^h\ 27^m$; $9\frac{1}{2}^h$ fainter; $9^h\ 40^m$ much fainter; $9^h\ 45^m$ just visible; $9^h\ 50^m$ invisible; 10^h just visible as a grey spot; $10^h\ 10^m$ a little darker; 10^h to $10\frac{1}{2}^h$ a grey spot, not dark. It had grown no darker at 11^h and $11\frac{1}{2}^h$, when clouds prevented further observation.

June 10. I. in transit, moving along the bright zone *d*. Ingress about $9^h\ 33^m$; $9^h\ 35^m$ fainter; $9^h\ 50^m$ just visible; 10^h invisible; $10^h\ 10^m$ a grey spot, and there was no further change up to 11^h. It was on the central meridian about $10^h\ 33^m$.

Sat. III. in transit moving along the S. edge of the N. polar shading; at 11^h it was very faint indeed.

June 17. IV. in transit moving in the grey N. polar region, and not far from the pole; at $9^h\ 33^m$ it was perhaps just fully on the disc; $9^h\ 40^m$ invisible; $9^h\ 50^m$ a faint grey spot; 10^h spot a little darker; $10^h\ 10^m$ still darker, and so it remained till $10^h\ 30^m$, when clouds hid the planet; it was not black.

Observations of the Variable Stars (2100) U Orionis and (4896) T Centauri. By Colonel E. E. Markwick.

U Orionis.—There has been some discussion as to the length of period of this star, which is even now to a certain extent unsettled, although better known than when the data were more limited, for the star has only been observed as a variable since 1885 December 13, when it was first discovered by Mr. Gore. The discoverer made the period 373·47 days (see *Monthly Notices*, vol. l. p. 518). Dr. Chandler in his 2nd Cat. of Variable Stars gave 371 days, with periodic inequality. In the 3rd Cat. this period is changed to 375 days, and I think from what follows this latter period is not far from the truth.

I have observed this star at every period of maximum from 1886 to 1898, except the year 1893, when only one observation was made. The observations have been made usually with a binocular magnifying five times, supplemented by a $2\frac{3}{4}$-inch refractor. My "date of maximum" is the day on which the star's brightness, when reduced from the comparison stars, was actually greatest. It has not been taken symmetrically as regards the light curve near time of maximum.

The comparison stars and brightness are as follows, the latter being mostly adopted from the *Harvard Photometry* :—

			m.
D.M.	+ 20	1156	6·57
	+ 19	1126	5·85
	+ 19	1110	6·08
	+ 20	1171	8·2
	+ 20	1168	8·6
	+ 20	1172	10·0
χ^1 Orionis			4·65
χ^2 ,, (Proctor) = H.P. 1119			5·08

The light curve of this star is very flat near maximum, hence there are bound to be considerable divergencies between the results of different observers. I have therefore taken the mean of my own and all the observations to be found in the summaries of astronomical publications given in the *Journal* of the *B. A. A.* The following table shows my dates of maximum with observed brightness, also the mean of all the observed dates of maximum from 1892, this portion being a revision and continuation of the table at p. 531 of *Monthly Notices*, vol. liv. The last column gives the interval in days between these mean results :—

Observed Date of Maximum.	Mag.	Mean of all Observations.	Interval in Days.
1886 December 16	6·12	...	...
1887 „ 16	7·26	...	...
1888 „ 29	5·49	...	...
1889 (no maximum).	...	...	...
1890 January 16	6·27	...	...
1891 „ 9	6·3	...	...
1892 „ 23	6·27	January 31	376
1893 (not observed)	...	February 10	369
1894 February 8	6·07	„ 14	377
1895 „ 24	6·08	„ 26	386
1896 March 19	6·27	March 18	360
1897 „ 11	5·61	„ 13	384
1898 „ 31	6·33	April 1	...
		Mean ...	... 375·3

Also, if we take the interval between two well-determined and most widely separated maxima, and divide by the number of periods elapsed, we get exactly the same result again. Thus:—

		Julian.
1886 December 12		241,0253
1898 April 1		241,4381
Difference	...	4128
Dividing by 11	...	375·3

It seems very probable, therefore, that at present we cannot better this.

The following table shows the comparison of observation and computation based on this period of 375·3 days. It will be observed that the residuals are fairly small except for 1894, 1896, and 1897, in each of which years moonlight was present and probably affected determinations of maximum brightness:—

Year.	Maximum. Computed.	Maximum. Observed.	O—C
1886	0252	0253	+1
1887	0628	0626	−2
1888	1003	1001	−2
1889	1378	1377	−1
1891	1754	1752	−2
1892	2129	2129	0
1893	2504	2505	+1
1894	2879	2874	−5
1895	3255	3251	−4
1896	3630	3637	+7
1897	4005	3997	−8
1898	4381	4381	0

The only thing that militates against this period is the fact that it does not fall in so well with the ancient dates referred to by Chandler in the *Astronomical Journal*, No. 233, p. 133, as when the period 373·47 days is used. The omission of the star from the observations of Lalande, Bessel, &c., would imply that at those dates it was probably in its fainter stages of brightness. Using a uniform period of 375·3 days, the following shows the distance in time each observation of neighbouring stars was before or after maximum :—

No.	Authority which failed to observe the Star.	Date of Observation of Vicinity.	Difference in Days from Computed Maximum.
1	Lalande	1797 February 17	152 before
2	Bessel	1826 March 3	56 „
3	Markree Observatory	1850 December 30	5 after
4	Schönfeld	1853 November 6	79 before
5	Markree	1854 „ 24	71 „
6	Schönfeld	1855 February 18	15 after
7	Krüger	1857 „ 9	14 before

In the case of 3, 6, and 7, supposing the period of 375·3 days correct, then the star was not far from maximum at these dates, and probably not below 7 m. Hence it is difficult to say why the star was missed ; yet at the same time too much stress must not be laid upon negative evidence. In the other four cases the star was sufficiently far from maximum to account for its being missed.

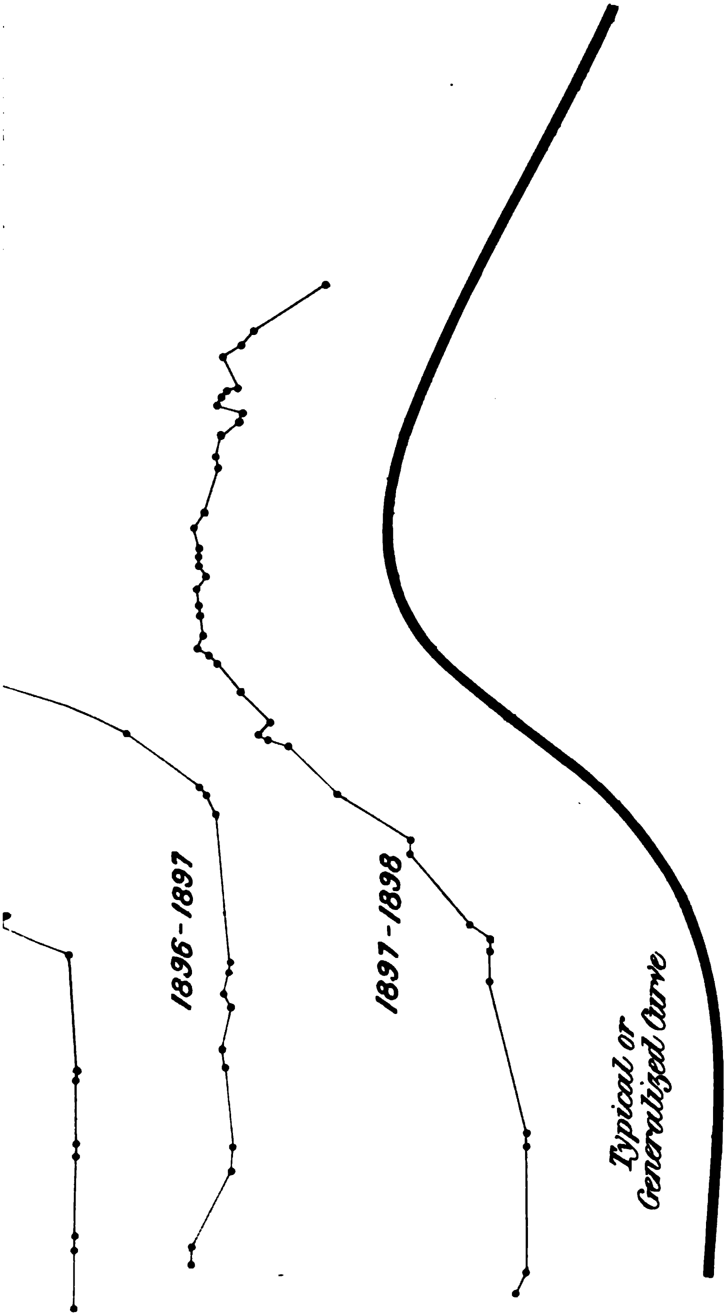
Plate 7*a* shows the observed brightness for eleven seasons, based on my own determinations alone.

These amount altogether to 307 in number.

The proportion adopted between length representing time (abscissa) and length representing brightness (ordinate) is ten days = 1 magnitude.

Many of the apparent irregularities or departures from a mean curve thus revealed are doubtless due to errors of observation from the various causes which constantly hamper the observer of variable stars. Apart from these, however, some of the fluctuations noted I am convinced are real. For example, in nearly all the curves just after the maximum there is a drop, and then a small recovery, which probably actually occurs. Mr. Peek shows a similar feature in his observations of *S Ursæ Majoris* (Variable Star Notes, No. 3).

I have added a typical or generalised curve, which is a rough mean of all the others, to give a general idea of the star's variation, but I am no believer in smoothed curves, and am confident that in nature gradual increase or decrease in light is subject to certain minor irregularities or fluctuations, which, however, cannot always be easily detected, owing to their minuteness. I do not see any more reason for the curve of light variation being smooth than that of the waxing and waning of sun spots.



OBSERVATIONS OF U ORIONIS.

T Centauri.—This star, the variability of which was first detected by me at Gibraltar in 1894, has been observed as frequently as possible since. Mr. Roberts has investigated the period (see *Monthly Notices*, vol. lvi. pp. 347 and 500) and shape of the light curve, and from what follows I do not think that his period of 91·5 days can be improved upon.

My observations were made in the same way as those of *U Orionis*. Comparison stars, with brightness :—

L 5649	7·0 m.	
244 (U.A.) Centauri	7·0	
237 Centauri	6·7	
241 {L 5613, L 5615} Centauri	6·8	
286 Centauri	6·0	
267 Centauri	5·8	
287 Centauri	6·6	
233 Centauri	6·8 (var.)	
A	7·4	These two stars are s.p. L 5649 at a little greater distance than that separating T from L 5649.
B	7·8	
C	10	R.A. $13^h\ 34^m{\cdot}6$, Dec. $-33°\ 7'$ (1875), 8·8 in C.D.M.
D	10·2	R.A. $13^h\ 34^m$, Dec. $-33°\ 0'$, 8·4 in C.D.M.

The observations of maxima, together with the deduced period, are shown in the following table :—

	Mag.	Interval.	Corresponding Length of One Period.
1894 May 25	6·25		
		379	94·7
1895 June 8	5·3		
		376	94·0
1896 June 18	6·4		
		348	87·0
1897 June 1	6·17		
		367	91·7
1898 June 3	6·6		
	Mean	...	... 91·85

Also if we take the interval from the first to the last of these determinations we get 1,470 days, corresponding to a period of 91·9 days.

The observations of minima, which, however, are not so definite as those of maxima, are as follows :—

		Interval.	Corresponding Length of One Period.
1894 July 24	<8·5		
		276	92·0
1895 April 26	10·0		
		370	92·5
1896 April 30	9·9		
		718	89·8
1898 April 18	9·2		
	Mean	...	... 91·4

Also from the first to the last of these dates is 1,364 days, corresponding to fifteen periods of 90·9 days each.

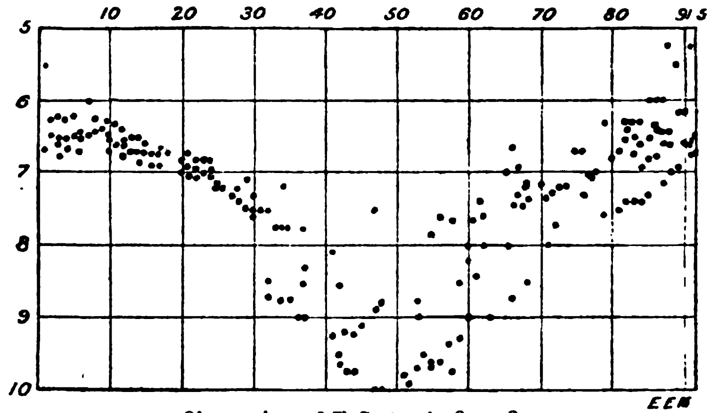
The mean of these four determinations is 91·51 days.

With the adopted period of 91·5 days the residuals come out as follows :—

Year.	Maximum (Julian). Computed.	Observed.	O—C
1894	2988	2974	−14
1895	3354	3353	− 1
1896	3720	3729	+ 9
1897	4080	4077	− 3
1898	4446	4444	− 2

There are but few observations of this star to hand, as it can only be reached from the extreme south of Europe. Mr. Tebbutt observed a maximum on 1896 March 8. This is only one day before the computed time.

Another maximum was observed and recorded in *A. J.*, 49, as on 1897 May 29. This is six days before computation.



Observations of *T Centauri*, 1894–98.

Based on the 91·5-day period all the observations of my own, in No. 203, have been plotted according to phase, *i.e.* to the length of time elapsed from next preceding maximum. The general shape of the light curve is at once apparent, the minimum occurring some forty-eight days after maximum, thus practically agreeing with Roberts's result, forty-nine days.

Unless some long-continued and egregious blunders in determination of brightness have been made, it is plain that the intrinsic brightness varies in different periods, and to a considerable extent. One can trace two, if not more, lines in the ascending branch. Hence I do not think the light curve is ever so smooth

and regular as that given by Roberts at p. 350 of *Monthly Notices*, in the first of the papers previously referred to. The brightness undoubtedly varies in different periods, and I think the general curve is subject to minor irregularities, as in the case of *U Orionis*.

Observations of Nebulæ. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

The following notes are in continuation of those published in the April, 1898, number of the *Monthly Notices*, and were made in the course of my observations upon nebulæ, during the first six months of 1898. The numbers, as previously, are the current ones of the N.G.C., except those which are enclosed in brackets, which refer to Dreyer's Index Catalogue in vol. li. of the *Memoirs of the R.A.S.* When, instead of a number, the name Swift is given, reference is made to objects recently discovered at the Lowe Observatory, found in lists published from time to time in various periodicals, chiefly in the *Monthly Notices*.

As the positions of so many of the nebulæ in my working list are erroneous, because of the inaccurate places given by the discoverers, I have striven not to add new errors by mistakes of my own, and have therefore determined the position of each comparison star twice, once by means of the circles of the instrument, and a sidereal watch, and a second time by connecting it with some catalogue star by chronographic and micrometric measures. There are two checks against gross errors in the micrometric measurements between each nebula and its comparison star. These are, firstly, independent estimates of $\Delta\alpha$ and $\Delta\delta$ by the help of the known intervals between the micrometer wires, and, secondly, sketches of the field of view. In a few cases a larger telescope, or a keener eye, may be needed to settle doubtful points. All positions are referred to the mean equinox of 1900·0.

The new Bruce micrometer, to which reference was made in my former communication, has now been in use for six months, and has proven itself to be a most admirable instrument. It has a set of eleven wires in R.A., and nine in declination, the latter spanning a space of 30′; the sets can be illuminated separately or simultaneously, with any desired intensity. The micrometer screw has movable heads, so that three bisections can be made before the readings are taken. The box can also be revolved just 90°, without reading the position-circle.

(195) and (196). These two nebulæ were not at all difficult to see, and I found no others in their neighbourhood. Hence I assume the ones which I observed to be those found by

Swift, though their relative positions are not as given by him. Their positions are :—

$$1^h\ 58^m\ 20^s,\ +14^\circ\ 13'\cdot7,$$
$$1^h\ 58^m\ 25^s,\ +14^\circ\ 15'\cdot5.$$

1121. The position is $2^h\ 45^m\ 35^s$, $-2^\circ\ 8'\cdot8$.

1337. Swift described this as "m E n s." I estimated the elongation to be at 135°.

(346). I measured (345), and its place agrees with that given by Dreyer within 1′. But in the place of (346), which was presumably discovered by Professor Stone at the same time, I saw nothing but faint stars. The seeing was excellent, and Professor Stone described (346) as brighter than (345).

1489. The position is $3^h\ 53^m\ 11^s$, $-19^\circ\ 30'\cdot3$.

1518. The elongation is at 200°. The position is $4^h\ 2^m\ 29^s$, $-21^\circ\ 26'\cdot6$.

1561–5. I could not see all the nebulæ in this group, but found a new one near by. Since the positions of these nebulæ are poor, a large telescope may well give attention to them.

1592. In the place given for this I found only small stars. 1591, near by, was observed.

1614. The position is $4^h\ 29^m\ 11^s$, $-8^\circ\ 47'\cdot3$.

1619. In the place given for this I saw only stars of mags. 13–14. Its neighbour, 1627, was readily seen.

1689. Swift called this "pB." I searched for it on two nights without success. Probably there was an error of just 5^m in its R.A., and it is identical with 1667, which has the same declination.

1729. The N.G.C. description is "vF, pL, 2 B st v nr." My description was "F, pS, R, with nucleus of mag. 13·5." It is in line between two stars of mags. 8·5 and 9 respectively, the former preceding it $20^s\pm$, on nearly the same parallel, and the latter following it 4^s.

1738. The position is $4^h\ 57^m\ 22^s$, $-18^\circ\ 18'\cdot1$.

1739. The position is $4^h\ 57^m\ 23^s$, $-18^\circ\ 18'\cdot7$.

1744. This is very large, faint, and ill defined. But it contains a nuclear point of mag. 12·8. The position is $4^h\ 55^m\ 52^s$, $-26^\circ\ 10'\cdot4$.

1781. On two nights I was unable to find this, though I measured 1794, which is similar in description. As the N.G.C. R.A. of 1781 differs from my R.A. for 1794 by 3^m, and the declinations of the two objects differ by less than 1′, it is probable that H. made an error of 3^m in the place of 1781.

1794. The position is $5^h\ 3^m\ 31^s$, $-18^\circ\ 19'\cdot2$.

2054. I saw only three small stars. The 9 mag. star which Bond said to be 7′ north was seen.

2124. H.'s description is "eeF, pS, E, r," while I called it simply "F, S." However, I noticed a star of mag. 14 just south, and one of mag. 13 40″ further south. A rude representation of the nebula, which I drew, makes it elongated at 180°. Its position is $5^h\ 53^m\ 33^s$, $-20°\ 5'{\cdot}6$.

Swift. This is in Swift's List No. 6. Its position is $5^h\ 53^m\ 43^s$, $-23°\ 11'{\cdot}4$.

Swift. This is in Swift's List No. 6. Its position is $5^h\ 56^m\ 59^s$, $-23°\ 40'{\cdot}5$.

2179. *h.* described this as "vmE." I looked carefully for elongation, and could perceive none. Two 12 mag. stars flank the nebula, on opposite sides; perhaps *h.* thought them to be portions of the nebula.

2206. This contains a 13·5 mag. double star, whose angle is 80°, and distance 10″.

2207. This is binuclear at 260°; the following nucleus is the brighter.

2211. The position is $6^h\ 14^m\ 8^s$, $-18°\ 29'{\cdot}8$.

2237. This seems to be the brightest point in a large nebulous region, which covers the entire background of the sky in this vicinity, though not with even brilliancy. Swift described it as a part of a ring surrounding a cluster. This appearance I could not verify, possibly because my field of view is much smaller than his. The position is $6^h\ 25^m\ 21^s$, $+5°\ 4'{\cdot}9$.

2280. *h.* described this as "lE." It appeared to me to be very narrow, and elongated at 160°, the southern end being extremely faint, and terminating at or near a star of mag. 13·5. But the definition was poor when I observed it, so that I may have missed faint lateral nebulosity, which would make the nebula appear less narrow.

2295. This nebula precedes the double 2292–3, instead of following it. The note in the N.G.C. should read, "D neb f." In other particulars the N.G.C. descriptive notes on these nebulæ agree with my observations. The position of 2295 is $6^h\ 43^m\ 23^s$, $-26°\ 37'{\cdot}6$.

2292. The position is $6^h\ 43^m\ 39^s$, $-26°\ 38'{\cdot}1$.

2293. The position is $6^h\ 43^m\ 42^s$, $-26°\ 38'{\cdot}6$.

2296. The position is $6^h\ 44^m\ 12^s$, $-16°\ 47'{\cdot}3$.

(454). One or two stars are involved in this nebula. Its position is $6^h\ 45^m\ 28^s$, $+13°\ 2'{\cdot}4$.

2325. *h.* called this "lE." To me it appeared round, with two 13 mag. stars near by, on opposite sides of it, at angles of 160° and 340° respectively.

2327. The double star involved in this very faint nebula is of mags. 9 and 12, at an angle of 110°, and distance of 7″.

(468). This nebula of Bigourdan's is supposed to precede 2361 by a little over 1^m. But I could not find any such object, though I examined the vicinity on three nights.

2359 and 2361. In the N.G.C. 2359 is called "vv L," but there is apparently an error of 1^m in its R.A. When Bigourdan discovered 2361, he probably thought it different from 2359, because the R.A. which he obtained was 1^m different. 2361 is really a small condensation in 2359. I examined these objects on three nights, one of which was exceptionally fine.

2382. I searched for this on two nights (on one of which the definition was good) in vain; on each occasion I saw 2380, which has a similar description, and was an easy object. I called it "pB, with good nucleus."

2409. This consists of ten scattered stars.

2438. In the N.G.C. this is described as a planetary nebula. I found it to be nearly uniform in brightness, but darker in the centre. It contains two stars of mags. 13 and 14 respectively, and many more were suspected. It is slightly elliptical at 135°. It lies in the elegant cluster 2437, and is one of the prettiest objects in the sky.

2440. In the N.G.C. this is described as a planetary nebula, which is not very well defined. I found it to be binuclear at 160°. There is also a very faint condensation at the preceding end of the nebula. The object is small, greenish, and very bright.

2470. The elongation is at 120°. A double star of mag. 9, angle 220°, and distance 3″, precedes it 11^s, 1′·4 north.

2491. Swift calls this "eeF," and puts it 15^s preceding 2496, and following a "B ✱." 2496 was easily found near the place assigned for it; the "B ✱" appeared to be of mag. 10, and 2491, after careful scrutiny on a fine night, resolved itself into a few stars of mag. 14.

2496. My description tallies with Swift's, except that he says "✱ close f," while I found a star of mag. 11, 3^s preceding.

(487). Swift described this as round; it is elongated at 110°.

2506. *h.* corrected his N.P.D. of this object by −10′, to make it agree with that found by Harding and H., and the N.G.C. has followed him. As the cluster, when searched for, was evidently not at this N.P.D., I took a single careful reading of the declination circle, which put it 10′ farther south. The N.P.D. should therefore be 100° 24′·4 in the N.G.C.

2564. This is described in the N.G.C. as "vF, S, R, gbM." I found it to be extremely small, and elongated at 90°; it looked quite like a faint close double star.

2566. The N.G.C. description is "vF, cL, er." I found here two objects of mags. 11 and 12 respectively. The brighter one is certainly a very small nebula, or nebulous star. I could not be certain that its nebulosity extended to the 12 mag. star. This object was examined on three nights, two of which were fine.

2610. The 7·5 mag. star near this nebula is Schjellerup 3139, the catalogue position of which agrees with the circle-readings of my instrument; there is no other bright star in the neighbourhood. Therefore the N.G.C. place of the nebula is erroneous. The correct position is $8^h\ 28^m\ 42^s$, $-14°\ 53'·8$.

2616. Swift called this "R." To me it appeared elongated at 180°, having the appearance of a very faint nebulous double star, having a distance of 10″.

2662. I searched in vain for this, in the place given in the N.G.C., on three nights, and finally found it 10′ north of its supposed location. The star mentioned by *h.* is of mag. 13, and precedes 2^s, a trifle north. The position of the nebula is $8^h\ 40^m\ 52^s$, $-14°\ 45'·4$.

2690. The position is $8^h\ 47^m\ 35^s$, $-2°\ 13'·6$.

2848. In measuring this I bisected the brightest spot in it; perhaps that is 2847. Dreyer saw a star of mag. 11–12, 3′ n.f.; I saw two stars there, n.f. the brightest part of the nebula, near its edge, and possibly involved in it.

2978. The position is $9^h\ 38^m\ 23^s$, $-9°\ 17'·3$.

3143. The position is $10^h\ 5^m\ 10^s$, $-12°\ 5'·3$.

3292. The elongation is at 180°. The position is $10^h\ 30^m\ 33^s$, $-5°\ 39'·6$.

3321. The main body of the nebula appeared to lie about 15″ from the n.p. star (of mag. 12) which Leavenworth noted, at an angle of 135°. I was not sure that the nebulosity extended clear up to the star; I observed it on two nights. The position is $10^h\ 33^m\ 52^s$, $-11°\ 7'·4$.

3322. I searched for this on two evenings without success. On each evening 3321 was seen. Their descriptions are similar, and their right ascensions agree fairly; I am inclined to think them the same, though Common's approximate declination for 3322 differs from mine for 3321 by over 15′. There is a like discrepancy between his observations and mine in the case of his pair 3360–1.

3360 and 3361. I found the declination of 3361 to be $-10°\ 40'·9$, which is 14′ greater than Common's estimate. It is much elongated at 160°; a star of mag. 13 precedes it a trifle, and a 10 mag. star, which was suspected to be a close double at 130°, follows it several seconds, on nearly the same parallel. 3360 is round and very faint. It precedes 3361 about 10^s, 1′ or 2′ south. The R.A. of 3361 is between $10^h\ 39^m\ 25^s$ and $10^h\ 39^m\ 30^s$.

3404. The position given in the N.G.C. for this Common nebula is only approximate. I had only faint suspicions of a nebula in that position, and found a nebula near by, which, as it is pretty bright, and much elongated at 90°, I assume to be 3404. Its position is $10^h\ 45^m\ 20^s$, $-11°\ 34'·7$.

3421 and 3422. I could see nothing in the N.G.C. places for these Common nebulæ, on either of two nights. I found one very faint, round, and small nebula at $10^h\ 46^m\ 0^s$, $-11^\circ\ 55'\cdot1$. The position of this was measured on two nights. A star of 12 mag. follows it about 4^s. On the first night I suspected an extremely faint nebula $1'\cdot5$ north of it. On the second night I suspected another preceding the known nebula 12^s, $2'$ south, but the definition was poor, and it may have been a star.

3546. The position is $11^h\ 4^m\ 47^s$, $-12^\circ\ 50'\cdot1$.

3704. I have looked in vain for this on two nights, on each of which its neighbour 3707 was very easily seen and measured. It was called "pB" on one of the nights. I saw also the 9 mag. star which is said to be "2′ ssf" 3704. Yet both Tempel and Common call 3704 "vF," the same designation which they apply to 3707. Is it possible that 3704 is variable?

3711. The position is $11^h\ 24^m\ 22^s$, $-10^\circ\ 31'\cdot3$.

3779 and (717). These nebulæ may be identical, since each discoverer obtained only an approximate place of his nebula. I saw with assurance only one nebula, though I suspected another between it and 3775. The position is $10^h\ 33^m\ 47^s$, $-10^\circ\ 1'\cdot7$.

4038 and 4039. This is a remarkable double nebula. 4038 seems the larger. 4039 is elongated at 220° in comet fashion. 4038 has a faint condensation near its centre; two other condensations were suspected preceding and following it. Both are very diffuse, and at times their outlines appear to meet. The definition was only fair when these were examined.

4263 and 4265. I saw only one nebula here. It appeared to be elongated at 90°. I sometimes suspected that this elongation might be the result of duplicity, but the object was very diffuse, and gave no certain indication of doubling.

4722 and 4723. The N.G.C. place for these is only approximate, and Tempel evidently considered them as constituting a double nebula, each component being vF, vS. I found only one nebula, which was followed at an interval of 4^s by a star of mag. 11·5. The position of the nebula is $12^h\ 46^m\ 19^s$, $-12^\circ\ 47'\cdot1$.

4726. The N.G.C. place of this nebula of Tempel's seems to be considerably out, both in R.A. and declination. The correct position is $12^h\ 46^m\ 18^s$, $-13^\circ\ 40'\cdot6$.

4740. Near the place given for this in the N.G.C. are Nos. 4724, 4726 and 4727, together with a new one which I discovered. I could not find 4740, but found a nebula approximately $15'$ south and 20^s preceding, which tallied with Swift's description of 4740; (this is not the new one mentioned above). This entire region deserves careful

observation with a large telescope, because of the presumed errors in the places of 4726 and 4740.

Swift. In Swift's List No. 8, published in the 1898 March number of the *Monthly Notices*, is a nebula at $14^h\ 6^m\ 50^s$, $-30°\ 3'\ 33''$. Though he called it only "F," I saw nothing in this place, the nearest object being 5494, which is in the same field. They may be identical.

Swift. This is No. 25 in Swift's List No. 8 just mentioned. Its position is $14^h\ 28^m\ 39^s$, $-27°\ 4'\cdot 8$.

(1077). The position is $14^h\ 51^m\ 43^s$, $-18°\ 48'\cdot 6$.

(1081). The position is $14^h\ 53^m\ 16^s$, $-18°\ 50'\cdot 4$.

5898. This has a fine nucleus. Its position is $15^h\ 12^m\ 22^s$, $-23°\ 43'\cdot 9$.

(1115). Swift's description is "eeF, S, R, pB * sf." I found only a double star of mags. 12·5 and 13·5, with angle 315°, and distance 5″. A star of mag. 8·5 follows 7^s, $2'\cdot 5$ south. The night was clear and the definition fair.

5926. The position is $15^h\ 18^m\ 41^s$, $+13°\ 4'\cdot 3$.

6065 and 6066. Dreyer's note on these nebulæ, on p. 227 of vol. li. of the *Memoirs of the R.A.S.*, leads me to give their true positions. 6065 is at $16^h\ 2^m\ 45^s$, $+14°\ 9'\cdot 3$. 6066 is at $16^h\ 2^m\ 57^s$, $+14°\ 12'\cdot 7$.

6224. The position is $16^h\ 43^m\ 26^s$, $+6°\ 29'\cdot 4$.

6225. A double, of 13 mag. stars, is involved; its angle is 90°, and distance 10″. The position is $16^h\ 43^m\ 29^s$, $+6°\ 24'\cdot 0$.

6294. This follows 6293 closely, and appears to be simply a very faint double star of mags. 13 and 13·5, with an angle of 315°, and distance of 8″.

(1243). This was examined on two nights. It consists of five 12–14 mag. stars in a line, at an angle of 0°, the length of the line being 45″. A star of mag. 14 immediately precedes the northern end of the row.

6309. This is a close double nebula, at an angle of 160°. Both objects are extremely small, and are also bright.

6355. This appeared to be an extremely faint small round cluster of very small stars, having many outliers on the north, and some on the south also.

6401. This has a nucleus of mag. 13·5, at an angle of 315° from the 10·8 mag. star, which lies on the south following border of the nebula.

6476. I examined this region for quite a while, on a fine night. Large areas appeared to have a nebulous background, or else to be covered with myriads of very minute stars; I could not decide which was the case. I came across a small but striking "Loch im Himmel," at $17^h\ 55^m\ 0^s\pm$, $-28°\ 35'\pm$.

6526. This appeared to me not to be a nebula, but simply an aggregation of very faint stars.

(1290). This is simply a cluster of half a dozen small stars from mag. 12 down.

6717. The cluster in this nebula is composed of five stars of mag. 12. The southernmost two form a double of angle 0° and distance 3″. Two others form another double of angle 340° and distance 2″. The nebulosity surrounding these is very faint and formless.

Swift. In Swift's List No. 2, at $19^h\ 22^m\ 0^s$, $-36°\ 24'\cdot 1$, there is an object which he described as "B, eS, vE, stellar, close nebulous D * ?." In this position I found nothing, but about 20^s preceding it there seemed to be a close double, the star being elongated at 100°.

6797. This was discovered by Peters, and was described as "a neb. with 9 mag. * att. f." I could see no trace of nebulosity, but the 9 mag. * was preceded by a double of mag. 13, angle 180°, and distance 10″.

6816. In this is a star of mag. 13·5. *h.* noted a "* np." I saw only a star of mag. 14 at an angle of 20° and distance of 30″. The sky was dull, so that the nebula was difficult to measure.

List of Nebulæ discovered at the Chamberlin Observatory, University Park, Colorado. By Herbert A. Howe.

(*Communicated by the Secretaries.*)

While observing nebulæ and comets with the 20-inch refractor, I have from time to time chanced upon new nebulæ, a list of which follows. The positions of all, with one exception, have been micrometrically measured, and are given for 1900·0.

No.	Date.	R.A.	Dec.	Description.
	1895.	h m s	° '	
1	Jan. 15	0 48 17	+ 5 13·7	eF, S, bet. st. 12^m and 13^m
2	15	0 49 32	+ 5 13·9	11^m nebulous *. 9^m * p 10^s, $4'·5$ n.
3	June 24	0 53 41	+ 0 2·8	vF, eS, R, lbM.
4	July 3	1 21 41	− 4 1·3	12^m nebulous *. FD * 2' nf.
	1898.			
5	Jan. 14	4 18 7	−15 53·8	eF, vS. Near N.G.C. 1561–5.
6	Feb. 22	5 27 54	−13 59·9	vF, S. Near N.G.C. 1954 and 1957.
7	11	6 12 14	−21 20·4	eF, pS, f N.G.C. 2207 7^s.
8	16	8 14 31	−25 3·4	pB, vS, R, lbM, 6' n of N.G.C. 2566.
9	22	8 21 37	−12 58·5	F, vS, elongated at 90°, 1st of 3.
10	22	8 21 44	−12 58·7	eF, vS, 2nd of 3.
11	22	8 21 45	−12 57·9	vF, vS, 3rd of 3.
12	Mar. 23	8 41 30	−14 59·4	vF, eS, lE.
13	Feb. 23	9 0 58	−18 48·4	F, vS, R, 10' s of N.G.C. 2754, 2757, and 2758.
14	Apr. 25	11 10 32	−13 37·5	eF, S.
15	20	12 45 44±	−13 56	F, S, R, n of 11^m *.
	1897.			
16	Oct. 19	21 3 40	−23 17·1	eF, vS, diffic.
17	Sept. 30	21 34 15	−22 52·7	eeF, S, diffic. In field with N.G.C. 7103 and 7104. Another susp. 1' s.
18	Oct. 20	22 7 0	−23 27·1	eF, vS, f N.G.C. 7220 63^s.
19	Sept. 27	23 15 30	−22 41·8	eF, eS, nearly stell., 13^m; $9·5^m$, 5' n.
20	28	23 18 55	−12 24·6	vF, vS, f $9·5^m$ * 1^s.
	1894.			
21	Dec. 14	23 29 28	− 5 5·2	nebulous * $10·5^m$. Possibly close D *. Extended nebulosity susp. at 135° and 315°.
	1897.			
22	Oct. 1	23 46 20	−13 56·2	F, vS, R, bM = * $12·5^m$.

Notes.

I would like to call the attention of observers with large telescopes to No. 22 of the above list. Its position is near those of N.G.C. 7761 and 7776, neither of which can I find. The position of N.G.C. 7761 was micrometrically observed by its discoverer, and its R.A. (1900·0) is $23^h\ 44^m\ 19^s$. The description of No. 22 tallies well with that of N.G.C. 7761, except that there is no 10^m ✱ 8′ p. N.G.C. 7776 is supposed to follow No. 22 74^s, and is described as eF, vS, lE, gbM.

The following objects were not included in the preceding list, because their positions are not very accurate, and they were all looked for without success in 1897 October. The failure to see them at that time may, however, have been due to their extreme faintness.

Date.	R.A. h m s	Dec. ° ′	Description.
1894 Dec. 27	0 1 16	−0 38	eF, prob. S.
1895 Aug. 23	0 34 0	+5 25	eF, prob. S. Seen also on Aug. 24.
1895 Aug. 23	0 34 25	+6 4	nebulous ✱, prob. vF. Seen also on Aug. 24.
1894 Dec. 3	22 55 25	−8 40	eF, prob. S.

Observations of Comet h 1898 (Perrine-Chofardet) made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The observations were made with the Sheepshanks equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.	Observer.	☄ — ✱ R.A.	Corr. for Refraction.	Log Factor of Parallax.	☄ — ✱ N.P.D.	Corr. for Refraction.	Log Factor of Parallax.	No. of Comps.	Apparent R.A.	Apparent N.P.D.	Comp. Star.
1898. d h m s		m s	s		° ′ ″	″			h m s	° ′ ″	
Sept. 21 16 24 14	A. C.	+1 59·33	−0·04	9·6115	− 8 58·2	−0·3	0·7936	4	10 29 40·60	64 12 14·0	*a*
21 16 21 6	„	−2 46·70	+0·05	9·6116	+12 23·3	+0·4	0·7956	1	10 29 40·49	64 12 0·6	*b*

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the comet.

The initials A. C. are those of Mr. Crommelin.

Comparison Stars.

	Star's Name.	Assumed R.A. 1898·0.	Assumed N.P.D. 1898·0.	Authority.
		h m s	° ′ ″	
a	W.B. (2), X. 501	10 27 39·01	64 20 58·4	Cambridge Astr. Gesell. Catalogue and Paris Catalogue, 1860.
b	W.B. (2), X. 594	10 32 24·86	63 59 22·8	„ „ „ „

A proper motion of $+0^s{\cdot}0077$ in R.A. has been applied to star *a*, deduced from comparison with Lalande and Weisse's Bessel.

Royal Observatory, Greenwich:
1898 *Sept.* 27.

Observations of Comet 1898 (Coddington, June 11) made at Sydney Observatory.

(*Communicated by H. C. Russell, C.M.G., F.R.S., Government Astronomer.*)

1898.	Sydney M.T. h m s	Δ R.A. m s	Δ N.P.D. ′ ″	Cp.	Obs.	R.A. app. h m s	log. p. Δ	N.P.D. app. ° ′ ″	log. p. Δ	Red. ad. l. app. s	″	*
June 16	9 15 52	−1 34·14	+7 20·6	5	S.	16 10 28·11	$9·253_n$	117 54 57·4	0·029	+4·24	+13·5	1
23	8 47 30	+0 22·46	−0 27·4	8	S.	15 45 42·26	$9·110_n$	122 7 37·5	9·528	+4·29	+17·1	2
23	9 38 57	*			S.	15 45 34·45		122 8 53·7	9·372			
24	8 44 10	+0 38·93	−7 33·0	8	S.	15 42 7·91	$9·077_n$	122 41 43·7	9·373	+4·28	+17·6	3
24	9 31 27	*			S.	15 42 0·08		122 42 49·7	9·172			
27	9 9 5	*			L.	15 31 24·36		124 21 37·6	$9·018_n$			
July 4	9 30 14	−0 11·10	+2 47·8	3	S.	15 7 17·73	9·286	127 51 3·6	$9·617_n$	+4·15	+22·1	4
5	8 10 30	*			S.	15 4 11·64		128 16 43·1	$9·848_n$			
6	8 3 21	*			S.	15 0 58·15		128 43 8·5	$9·888_n$			
7	7 56 15	*			S.	14 57 47·71		129 8 56·9	$9·923_n$			

Observer : L.=H. A. Lenehan. S.=R. P. Sellors.

* Observed on the meridian with transit circle.

Mean Places of Comparison Stars for 1898·0.

*	R.A. h m s	N.P.D. ° ′ ″	Authority.
1	16 11 58·01	117 47 23·3	St. 8858. Cord. G.C. 22077. Yarnall, 6848
2	15 45 15·51	122 7 47·8	Cord. Z.C. 15ʰ 3084
3	15 41 24·65	122 48 59·1	Cord. G.C. 21386. Wash. Z. (1846) 25·2
4	15 7 24·68	127 47 53·7	Sydney Mer. Obs. 1898

Sydney Observatory:
1898 *July* 12.

Ephemeris for Physical Observations of

(Continued from

Greenwich Noon. 1898.	P.	L−O.	B.	A−L.	*B*.	Q.	E.
	°	°	°	°	°	°	°
Nov. 12	353.66	217.42	+15.90	−34.88	+ 1.19	283.39	37.43
14	354.05	218.04	16.05	34.61	1.61	283.51	37.02
16	354.41	218.60	16.17	34.28	2.03	283.62	36.58
18	354.76	219.12	16.27	33.91	2.45	283.71	36.10
20	355.08	219.60	16.35	33.50	2.87	283.77	35.58
22	355.36	220.04	+16.42	−33.06	+ 3.28	283.81	35.03
24	355.62	220.44	16.47	32.58	3.69	283.84	34.43
26	355.86	220.81	16.50	32.07	4.10	283.84	33.81
28	356.07	221.14	16.53	31.52	4.50	283.81	33.14
30	356.25	221.42	16.54	30.93	4.90	283.76	32.42
Dec. 2	356.40	221.66	+16.53	−30.29	+ 5.30	283.68	31.69
4	356.53	221.86	16.50	29.62	5.70	283.55	30.90
6	356.62	222.00	16.46	28.88	6.10	283.39	30.07
8	356.68	222.09	16.40	28.10	6.50	283.19	29.19
10	356.70	222.14	16.31	27.28	6.89	282.95	28.26
12	356.69	222.12	+16.20	−26.39	+ 7.28	282.68	27.28
14	356.64	222.05	16.08	25.45	7.67	282.35	26.26
16	356.56	221.92	15.94	24.45	8.05	281.99	25.17
18	356.44	221.75	15.78	23.41	8.43	281.56	24.03
20	356.28	221.52	15.61	22.32	8.81	281.06	22.84
22	356.09	221.23	+15.42	−21.16	+ 9.18	280.47	21.59
24	355.87	220.89	15.22	19.95	9.55	279.78	20.29
26	355.62	220.50	15.00	18.70	9.92	278.99	18.95
28	355.32	220.05	14.76	17.39	10.29	278.12	17.55
30	354.98	219.55	14.51	16.02	10.65	277.04	16.12
1899. Jan. 1	354.62	219.02	+14.25	−14.63	+11.01	275.74	14.63
3	354.23	218.44	13.97	13.18	11.37	274.14	13.12
5	353.81	217.82	13.68	11.72	11.72	272.28	11.57
7	353.37	217.17	13.39	10.18	12.07	269.77	10.01
9	352.92	216.50	13.09	8.64	12.41	266.45	8.43
11	352.45	215.80	+12.77	− 7.07	+12.75	261.70	6.87
13	351.94	215.07	12.45	5.47	13.09	254.29	5.34
15	351.44	214.32	12.13	3.85	13.43	241.71	3.95
17	350.94	213.57	+11.80	− 2.23	+13.76	218.40	2.91

Mars, 1898–99. By A. C. D. Crommelin.

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Greenwich Noon.	Light Time.	Appar. Diam.	Defect of Illumination. q	Central Meridian. ω_0	Passage of Zero Meridian.	
1898.	m	"	"	°	h m	h m
Nov. 12	8·10	9·85	1·01	115·00	16 46	16 8
14	7·98	10·00	1·01	96·20	18 4	17 25
16	7·86	10·16	1·00	77·45	19 20	18 42
18	7·74	10·32	0·99	58·74	20 37	19 58
20	7·62	10·49	0·98	40·08	21 54	21 15
22	7·49	10·66	0·97	21·45	23 10	22 32
24	7·37	10·83	0·95	2·87	...	23 48
26	7·25	11·01	0·93	344·31	1 4	0 26
28	7·13	11·19	0·91	325·79	2 20	1 42
30	7·01	11·38	0·89	307·33	3 36	2 58
Dec. 2	6·90	11·57	0·86	288·90	4 52	4 14
4	6·79	11·76	0·83	270·51	6 7	5 30
6	6·68	11·95	0·80	252·18	7 23	6 45
8	6·57	12·15	0·77	233·90	8 38	8 1
10	6·47	12·34	0·73	215·66	9 53	9 16
12	6·37	12·54	0·69	197·49	11 7	10 30
14	6·27	12·73	0·65	179·37	12 21	11 44
16	6·18	12·92	0·61	161·30	13 35	12 58
18	6·09	13·11	0·57	143·28	14 49	14 12
20	6·01	13·30	0·52	125·31	16 3	15 26
22	5·93	13·48	0·47	107·40	17 16	16 40
24	5·85	13·65	0·42	89·55	18 29	17 53
26	5·78	13·81	0·37	71·74	19 42	19 6
28	5·71	13·97	0·32	53·99	20 55	20 19
30	5·65	14·12	0·27	36·29	22 8	21 32
1899. Jan. 1	5·60	14·26	0·23	18·61	23 20	22 44
3	5·55	14·38	0·19	0·99	...	23 56
5	5·51	14·49	0·15	343·40	1 8	0 32
7	5·48	14·58	0·11	325·85	2 20	1 44
9	5·45	14·65	0·08	308·31	3 32	2 56
11	5·43	14·70	0·06	290·80	4 44	4 8
13	5·42	14·74	0·04	273·31	5 56	5 20
15	5·41	14·76	0·02	255·85	7 7	6 32
17	5·41	14·75	0·01	238·38	8 18	7 43

Greenwich Noon.	P.	L−Ω.	B.	A−L.	*B*.	Q.	R.
1899. Jan. 19	350°44	212°81	+11°48	− 0°60	+14°09	182°43	2°67
21	349·94	212·07	+11·18	+ 1·01	+14·41	152·54	3·39
23	349·44	211·33	10·88	2·62	14·73	135·80	4·65
25	348·94	210·61	10·59	4·21	15·05	126·53	6·09
27	348·47	209·91	10·32	5·79	15·37	120·73	7·61
29	348·01	209·23	10·05	7·35	15·68	116·85	9·13
31	347·58	208·58	+ 9·80	+ 8·88	+15·98	113·99	10·67
Feb. 2	347·17	207·97	9·58	10·37	16·28	111·74	12·16
4	346·79	207·40	9·38	11·82	16·58	109·97	13·62
6	346·44	206·86	9·19	13·24	16·87	108·55	15·04
8	346·11	206·36	9·03	14·63	17·16	107·39	16·42
10	345·81	205·92	+ 8·89	+15·95	+17·44	106·37	17·77
12	345·55	205·52	8·78	17·23	17·72	105·46	19·03
14	345·32	205·17	8·68	18·47	18·00	104·66	20·28
16	345·13	204·87	8·60	19·66	18·27	103·95	21·46
18	344·96	204·61	8·55	20·81	18·54	103·34	22·59
20	344·83	204·41	+ 8·53	+21·90	+18·80	102·84	23·65
22	344·73	204·25	8·55	22·96	19·06	102·43	24·69
24	344·67	204·13	8·58	23·98	19·31	102·07	25·66
26	344·63	204·06	8·61	24·95	19·56	101·75	26·58
28	344·63	204·04	8·66	25·87	19·81	101·47	27·45
Mar. 2	344·66	204·07	+ 8·73	+26·74	+20·05	101·24	28·23
4	344·72	204·14	8·82	27·57	20·29	101·04	29·00
6	344·79	204·25	8·93	28·36	20·52	100·89	29·73
8	344·90	204·40	9·06	29·12	20·74	100·77	30·41
10	345·04	204·60	9·22	29·83	20·96	100·68	31·06
12	345·20	204·83	+ 9·39	+30·51	+21·17	100·62	31·66
14	345·38	205·09	9·58	31·16	21·38	100·59	32·22
16	345·59	205·39	9·78	31·78	21·58	100·59	32·74
18	345·82	205·73	9·99	32·36	21·78	100·61	33·23
20	346·08	206·10	10·20	32·91	21·98	100·65	33·67
22	346·35	206·50	+10·43	+33·44	+22·17	100·71	34·08
24	346·64	206·93	10·67	33·93	22·35	100·80	34·46
26	346·95	207·39	10·93	34·39	22·53	100·90	34·81
28	347·29	207·88	11·20	34·82	22·70	101·02	35·14
30	347·64	208·41	11·47	35·22	22·87	101·15	35·43
Apr. 1	348·01	208·96	+11·75	+35·60	+23·03	101·30	35·70
3	348·40	209·53	+12·05	+35·96	+23·19	101·46	35·94

Greenwich Noon.		Light Time.	Appar. Diam.	Defect of Illumination. q	Central Meridian. ω_0	Passage of Zero Meridian.	
1899.		m	"	"	°	h m	h m
Jan.	19	5·42	14·72	0·01	220·92	9 29	8 54
	21	5·44	14·67	0·01	203·44	10 41	10 5
	23	5·47	14·60	0·02	185·96	11 53	11 17
	25	5·50	14·52	0·04	168·46	13 4	12 28
	27	5·54	14·42	0·06	150·93	14 16	13 40
	29	5·58	14·30	0·09	133·38	15 28	14 52
	31	5·63	14·17	0·12	115·81	16 41	16 4
Feb.	2	5·69	14·02	0·16	98·19	17 54	17 17
	4	5·76	13·86	0·20	80·52	19 6	18 30
	6	5·83	13·69	0·24	62·83	20 19	19 42
	8	5·91	13·50	0·28	45·09	21 32	20 55
	10	6·00	13·31	0·32	27·30	22 45	22 8
	12	6·09	13·11	0·36	9·46	23 58	23 21
	14	6·18	12·91	0·40	351·57	0 35	...
	16	6·28	12·70	0·44	333·63	1 48	1 11
	18	6·39	12·49	0·48	315·65	3 2	2 25
	20	6·50	12·27	0·52	297·61	4 16	3 39
	22	6·62	12·06	0·55	279·52	5 30	4 53
	24	6·74	11·85	0·58	261·40	6 44	6 7
	26	6·86	11·64	0·61	243·22	7 59	7 21
	28	6·98	11·43	0·64	225·00	9 14	8 36
Mar.	2	7·11	11·22	0·67	206·72	10 29	9 51
	4	7·24	11·02	0·69	188·40	11 44	11 6
	6	7·38	10·82	0·71	170·04	12 59	12 21
	8	7·52	10·62	0·73	151·64	14 15	13 37
	10	7·66	10·42	0·75	133·19	15 31	14 53
	12	7·80	10·23	0·76	114·71	16 47	16 9
	14	7·94	10·05	0·77	96·20	18 3	17 25
	16	8·08	9·87	0·78	77·65	19 19	18 41
	18	8·23	9·69	0·79	59·06	20 36	19 57
	20	8·38	9·52	0·80	40·44	21 52	21 14
	22	8·53	9·35	0·80	21·78	23 9	22 31
	24	8·68	9·19	0·81	3·10	...	23 47
	26	8·84	9·03	0·81	344·39	1 4	0 26
	28	8·99	8·88	0·81	325·65	2 21	1 42
	30	9·15	8·73	0·81	306·86	3 38	2 59
April	1	9·30	8·59	0·81	288·06	4 55	4 16
	3	9·46	8·45	0·81	269·23	6 12	5 33

Greenwich Noon.	P.	L−O.	B.	A−L.	*B*.	Q.	E.
1899. April 5	348°81	210°13	+12°35	+36°29	+23°35	101°63	36°16
7	349·22	210·75	12·66	36·60	23·50	101·81	36·35
9	349·65	211·40	12·97	36·89	23·64	102·00	36·52
11	350·10	212·07	+13·28	+37·16	+23·77	102·21	36·67
13	350·56	212·77	13·60	37·40	23·90	102·43	36·80
15	351·03	213·48	13·92	37·63	24·02	102·65	36·91
17	351·52	214·21	14·24	37·85	24·13	102·88	37·00
19	352·02	214·96	14·57	38·06	24·24	103·11	37·07
21	352·53	215·74	+14·91	+38·25	+24·34	103·34	37·13
23	353·06	216·53	15·25	38·42	24·44	103·58	37·17
25	353·60	217·34	15·59	38·57	24·53	103·82	37·19
27	354·14	218·17	15·92	38·69	24·62	104·07	37·20
29	354·70	219·02	16·26	38·79	24·71	104·32	37·20
May 1	355·27	219·88	+16·60	+38·89	+24·79	104·57	37·18
3	355·84	220·76	16·94	38·97	24·86	104·82	37·15
5	356·42	221·65	17·28	39·05	24·92	105·08	37·11
7	357·02	222·56	17·62	39·10	24·98	105·34	37·06
9	357·62	223·49	17·95	39·14	25·03	105·60	37·00
11	358·22	224·43	+18·28	+39·17	+25·08	105·86	36·92
13	358·84	225·39	18·61	39·18	25·12	106·13	36·83
15	359·47	226·36	18·94	39·18	25·15	106·40	36·74
17	0·10	227·35	19·27	39·16	25·17	106·66	36·63
19	0·74	228·35	19·59	39·14	25·19	106·92	36·52
21	1·38	229·36	+19·90	+39·11	+25·20	107·17	36·39
23	2·03	230·39	20·21	39·06	25·21	107·42	36·26
25	2·69	231·43	20·52	38·99	25·21	107·67	36·12
27	3·35	232·49	20·82	38·91	25·21	107·92	35·98
29	4·02	233·56	21·12	38·82	25·20	108·17	35·83
31	4·69	234·64	+21·42	+38·71	+25·18	108·41	35·66
June 2	5·37	235·73	21·71	38·60	25·15	108·65	35·49
4	6·05	236·83	21·99	38·48	25·11	108·88	35·32
6	6·74	237·95	22·26	38·34	25·07	109·11	35·13
8	7·43	239·09	22·53	38·18	25·03	109·33	34·94
10	8·12	240·24	+22·79	+38·02	+24·98	109·54	34·75
12	8·81	241·40	23·04	37·84	24·92	109·75	34·55
14	9·51	242·57	23·28	37·66	24·86	109·95	34·34
16	10·22	243·76	23·52	37·45	24·79	110·15	34·13
18	10·92	244·95	+23·75	+37·24	+24·71	110·35	33·91

Greenwich Noon.	Light Time.	Appar. Diam.	Defect of Illumination.	Central Meridian.	Passage of Zero Meridian.	
			q	ω_0		
1899.	m	″	″	°	h m	h m
April 5	9·61	8·31	0·80	250·38	7 29	6 50
7	9·76	8·18	0·80	231·51	8 47	8 8
9	9·92	8·05	0·79	212·60	10 5	9 26
11	10·07	7·92	0·79	193·68	11 23	10 44
13	10·23	7·80	0·78	174·73	12 41	12 2
15	10·38	7·68	0·78	155·77	13 59	13 20
17	10·54	7·57	0·77	136·78	15 17	14 38
19	10·70	7·46	0·76	117·78	16 35	15 56
21	10·85	7·35	0·75	98·74	17 53	17 14
23	11·01	7·25	0·74	79·70	19 11	18 32
25	11·16	7·15	0·73	60·64	20 30	19 50
27	11·32	7·05	0·72	41·55	21 48	21 9
29	11·47	6·96	0·71	22·45	22 7	22 27
May 1	11·62	6·87	0·70	3·33	...	23 46
3	11·78	6·78	0·69	344·20	1 5	0 26
5	11·93	6·69	0·68	325·06	2 23	1 44
7	12·08	6·61	0·67	305·89	3 42	3 2
9	12·23	6·53	0·66	286·71	5 1	4 21
11	12·38	6·45	0·65	267·52	6 20	5 40
13	12·52	6·37	0·64	248·31	7 39	6 59
15	12·67	6·30	0·63	229·09	8 58	8 18
17	12·81	6·23	0·62	209·85	10 17	9 37
19	12·96	6·16	0·60	190·60	11 36	10 56
21	13·11	6·09	0·59	171·33	12 56	12 16
23	13·25	6·02	0·58	152·05	14 15	13 36
25	13·39	5·96	0·57	132·76	15 34	14 55
27	13·53	5·90	0·56	113·46	16 53	16 14
29	13·67	5·84	0·55	94·14	18 12	17 33
31	13·81	5·78	0·54	74·81	19 31	18 52
June 2	13·95	5·72	0·53	55·47	20 51	20 11
4	14·08	5·67	0·52	36·12	22 11	21 31
6	14·21	5·62	0·51	16·75	23 31	22 51
8	14·35	5·56	0·50	357·36	0 11	...
10	14·48	5·51	0·49	337·96	1 30	0 51
12	14·61	5·46	0·48	318·55	2 50	2 10
14	14·74	5·41	0·47	299·14	4 10	3 30
16	14·87	5·36	0·46	279·70	5 30	4 50
18	15·00	5·32	0·45	260·26	6 50	6 10

Greenwich Noon.	P.	L−O.	B.	Λ−L.	*B*.	Q.	E.
1899. June 20	11°·62	246°·15	+23°·96	+37°·04	+24°·63	110°·54	33°·69
22	12·33	247·36	24·17	36·81	24·54	110·72	33·46
24	13·04	248·59	24·38	36·57	24·44	110·90	33·23
26	13·75	249·82	24·57	36·32	24·33	111·07	33·00
28	14·46	251·07	24·75	36·06	24·22	111·23	32·76
30	15·17	252·32	+24·92	+35·79	+24·11	111·39	32·52
July 2	15·87	253·58	25·08	35·52	23·99	111·54	32·27
4	16·57	254·85	25·23	35·23	23·86	111·69	32·02
6	17·27	256·13	25·37	34·94	23·72	111·83	31·76
8	17·97	257·42	25·49	34·64	23·58	111·96	31·50
10	18·67	258·72	+25·60	+34·33	+23·43	112·08	31·24
12	19·37	260·04	25·71	34·00	23·28	112·19	30·98
14	20·07	261·37	25·81	33·66	23·12	112·29	30·71
16	20·76	262·70	+25·90	+33·32	+22·95	112·38	30·44

The constants are the same as those employed in the first portion of the ephemeris.

L−O+180°, Λ−O+180° are the longitudes of the Earth and Sun referred to the plane of *Mars'* equator and reckoned from O, the point of the vernal equinox of *Mars'* northern hemisphere ; thus Λ−L is the angle between the meridians of *Mars* which are central to the Earth and to the Sun ; B, *B* are the latitudes of the Earth and Sun reckoned from the plane of *Mars'*

Greenwich Noon.	Light Time.	Appar. Diam.	Defect of Illumination.	Central Meridian.	Passage of Zero Meridian.	
			q	ω_0		
1899.	m	″	″	°	h m	h m
						7 30
June 20	15·12	5·28	0·44	240·82	8 10	
						8 50
22	15·24	5·24	0·43	221·36	9 30	
						10 10
24	15·36	5·20	0·42	201·89	10 51	
						11 31
26	15·48	5·16	0·42	182·41	12 11	
						12 51
28	15·60	5·12	0·41	162·92	13 31	
						14 11
30	15·72	5·08	0·40	143·42	14 51	
						15 31
July 2	15·84	5·04	0·39	123·92	16 11	
						16 51
4	15·95	5·00	0·38	104·40	17 31	
						18 11
6	16·06	4·97	0·37	84·88	18 51	
						19 31
8	16·17	4·93	0·37	65·35	20 11	
						20 51
10	16·28	4·90	0·36	45·81	21 32	
						22 12
12	16·39	4·87	0·35	26·24	22 52	
						23 32
14	16·50	4·84	0·34	6·67	...	
						0 13
16	16·60	4·81	0·33	347·10	0 53	
						1 34

equator, Q the position angle of the greatest defect of illumination, q the amount of the greatest defect of illumination, E the areocentric angle between the Earth and Sun.

The spring equinox of Mars' northern hemisphere occurs 1898 November $6^{d}\cdot3$, and the summer solstice 1899 May $24^{d}\cdot2$.

Benvenue, Ulundi Road, Blackheath, S.E.:
1898 *September* 28.

Erratum in Mr. MERRIFIELD's *paper*, vol. lviii. p. 457, second term of right-hand member of last equation :

$$for \quad [7{\cdot}1638 - 10] \left(\frac{d^2 d}{d t^2} + \frac{d \mu}{d t}\right)$$

$$read \quad [7{\cdot}1638_n - 10] \left(\frac{d^2 d}{d t^2} + 1\frac{d \mu}{d t}\right) \sin \alpha.$$

INDEX.

T T

APPENDIX.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

APPENDIX TO VOL. LVIII.

[*From Proc. Roy. Soc.*]

"Report on the Expedition to Sahdol, Rewah State, Central India, to observe the Total Solar Eclipse of 1898 January 22." By W. H. M. CHRISTIE, C.B., M.A., F.R.S., Astronomer Royal, and Professor H. H. TURNER, M.A., F.R.S. Received May 25, 1898.

The Report is presented in three parts.

Part I is a joint Report by the two observers.

Part II is a separate Report by the Astronomer Royal; and

Part III is a separate Report by Professor Turner.

PART I.

1. This expedition was organised by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee.

The Government of India made excellent arrangements for the party, and the Surveyor-General of India with the staff of his Department rendered great service in selecting a site, clearing the jungle, establishing a camp, erecting the instruments, and in giving every assistance in the observations, for all of which the observers desire to tender their thanks.

The observers are also indebted to the Great Indian Peninsular Railway, the Bengal and Nagpur Railway, and the East Indian Railway for great liberality in granting facilities and in making special arrangements for the safe conveyance of their instruments from Bombay to Sahdol.

2. *Personnel.*—The following persons took part in the expedition :—

W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

H. H. Turner, M.A., F.R.S., Savilian Professor of Astronomy at Oxford.

Harold A. H. Christie, who gave the exposures throughout the eclipse for the Astronomer Royal.

It was originally proposed that Dr. A. A. Common, F.R.S., should also take part in this expedition, but he ultimately found that he was unable to do so, and Dr. Copeland, Astronomer Royal for Scotland, was invited by the J.P.E. Committee to go in his place. Dr. Copeland preferred, however, not to join any of the three other expeditions, but to establish himself independently.

3. *Itinerary.*—The observers left Marseilles in the Peninsular and Oriental steamship "Ballaarat" (R.M.S.), on Thursday morning, December 16, 1897, their instruments having been put on board this vessel in London ten days earlier. They arrived at Bombay on Monday morning, January 3, 1898, the weather during the voyage being excellent. After a few days spent in landing the instruments and arranging for their journey to Sahdol, they left Bombay on Friday evening, January 7, travelling direct to Sahdol by special arrangements courteously made by the G.I.P., East Indian, and Bengal and Nagpur Railways, and arrived at Sahdol in the early morning of Sunday, January 9.

4. *Selection of a Station.*—The J.P.E. Committee originally proposed for this expedition a station south of Poona, either near Karad on the S. Maratha Railway or near Jeur on the G.I.P. Railway, other expeditions occupying stations near Viziadrug on the coast, and Pulgaon on the Nagpur branch of the G.I.P. Railway.

The Surveyor-General of India having offered to give every assistance to the expeditions, appointed Major Burrard, R.E., to make all necessary arrangements, including the determination of exact local time and of the longitude and latitude of the station. Major Burrard selected Karad, in the Satara district, as the best tation. Owing, however, to the outbreak of plague at that place, and its prevalence in the Bombay Presidency, it was finally decided, on the advice of the Bombay Government, to abandon this choice and to occupy a station at Sahdol, on the railway to the east of Pulgaon, connecting Katni and Bilaspur. As this site was in dense jungle, it was necessary to clear a considerable space for the camp, part of which was to be occupied by a party under Mr. Michie Smith, Government Astronomer at Madras. This clearing, the establishment of the camp, and the erection of piers and huts for the instruments and of a dark room for photography, were all admirably carried out by Major Burrard, R.E., and his assistant, Lieutenant Crosthwait, R.E., before the arrival of the observers, who thus found everything ready for the setting up of their instruments.

5. *Position of Station.*—The observing station was about three-quarters of a mile from the railway station, on the south side of the line. The position of the centre of the pier on which the cœlostat used by the Astronomer Royal was mounted is—

Longitude 81° 21′ 33″ E. = $5^h\ 25^m\ 26^s{\cdot}2$ E.
Latitude 23° 16′ 45·3″.
Height above mean sea level 1502·4 feet.

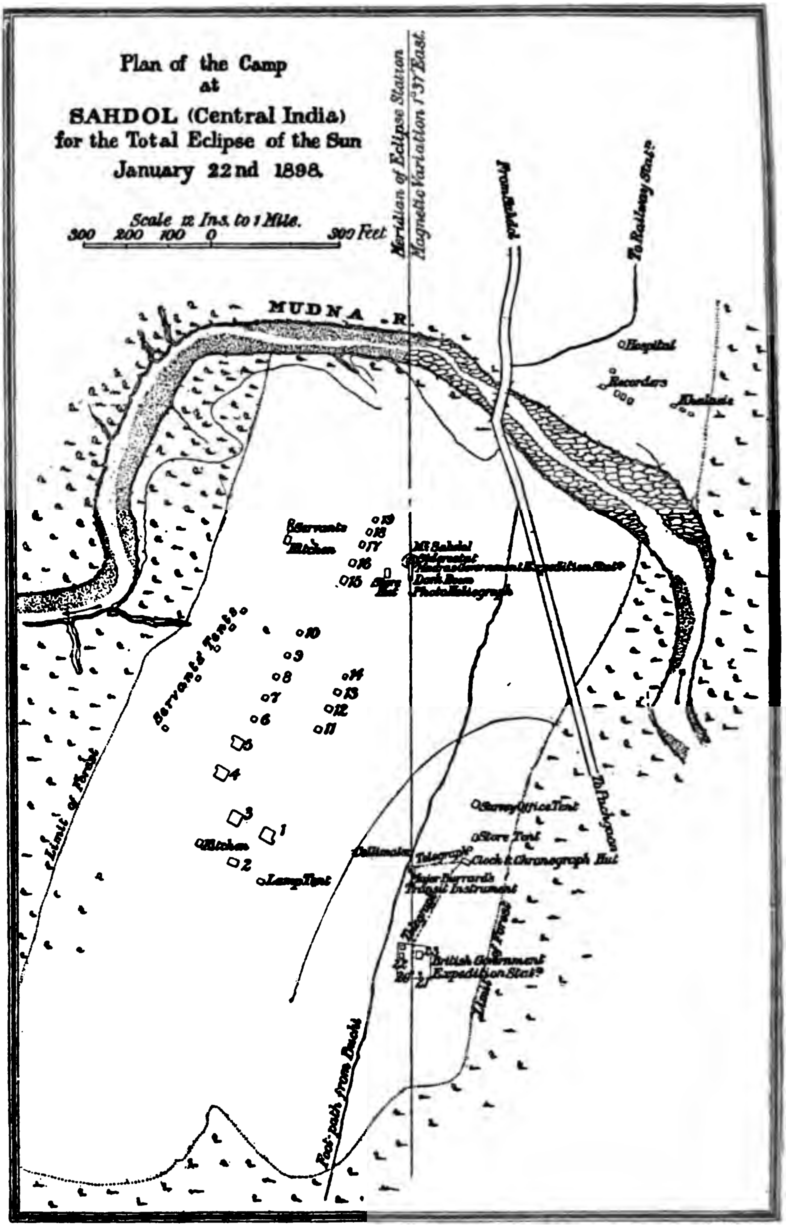
This position was determined after the eclipse by Major Burrard, R.E., by accurate triangulation, connecting the site with the principal triangulation of the Survey of India.

Professor Turner's cœlostat was 20 feet due east of this, and the transit instrument (used by Major Burrard in his time determinations) 240 feet due north of it.

This spot is 4 miles towards the south-east from the central line as shown in the 'Nautical Almanac' and 'American Ephemeris,' 3¼ miles from the line as shown in the 'Connaissance des Temps,' and 2 miles from the line as shown in the 'Berliner Jahrbuch.' It may be remarked that the data for predicting the four contacts given in the 'Nautical Almanac Circular No. 16' were found insufficient, the nearest points for which approximate formulæ were given being in longitude 79° (Nagpur) at a considerable distance from the central line, and in longitude 83° (south of Benares), too far away to give accurate predictions. [See Professor Turner's separate Report.]

6. *The Camp.*—The general arrangements of the camp (see next page), which consisted of more than fifty tents and huts, were, as already mentioned, admirably carried out by Major Burrard, R.E., it being necessary to clear a considerable space (about 700 by 300 yards) in the jungle by burning and felling trees, in order to set up the numerous tents of the living camp at some distance from the observing huts. On part of this clearing the Government Astronomer at Madras (Mr. Michie Smith) and his assistants erected their camp and instruments, and Major Burrard rendered considerable assistance to this party. There were also several tents for occupation by distinguished officers of the Survey, and we had the pleasure of seeing at the camp on the day of the eclipse the Surveyor-General (General Strahan, R.E.), General Woodthorpe, R.E., Colonel Sir T. Holditch, R.E., and other officers, and for a few days preceding the eclipse Colonel Gore, R.E., who left us for the Pulgaon Camp on January 19.

7. *Meteorological Conditions.*—From valuable information collected by Mr. Eliot, Meteorological Reporter to the Government of India, it appeared that the chances of fine weather were practically the same all along the line of totality, there being very little risk of cloud, though some chance of dust interfering with the definition. The thickly wooded country round Sahdol seemed well adapted for protection from the danger of dust, and during the days near the eclipse the ground near the instruments was covered with straw and watered in the morning to prevent excessive heating of the air in the



REFERENCE.

1. { Mr. W. H. M. Christie, C.B., F.R.S.
   Master Harold Christie.
2. Lieut. H. L. Crosthwait, R.E.
3. Mess.
4. Professor H. H. Turner, F.R.S.
5. Major S. G. Burrard, R.E.
6. Mr. C. H. McA'Fee.
7. Mr. R. George.
8. Captain E. D. Bullen, R.E.
9. Colonel Sir T. H. Holditch, K.C.I.E., C.B., R.E.
10. Captain J. A. Dealy, R.E.
11. { General C. Strahan, R.E.
    Colonel St. G. C. Gore, R.E.
12. General R. G. Woodthorpe, C.B., R.E.
13. Mr. C. Michie Smith.
14. Captain W. Ewbank, R.E.
15. { Mr. A. H. Campbell, I.C.S.
    Surgeon-Major J. L. Van Geyzel, I.M.S.
16. Madras Mess.
17. Doctor J. W. Evans.
18. { Mr. F. W. Lawrence.
    Mr. A. F. N. Moos.
19. { Mr. R. Ll. Jones.
    Mr. H. Kelsall Slater.
20. Mr. Christie's cœlostat { Lat. 23°16′45″·3 N. Long. 81°21′33″·0 E. Height 1502·4 feet.
21. Professor Turner's cœlostat.
22. Dark room.
23. Instrument tent.

path of the rays from the sun to the cœlostats, which were placed at a height of only 2 feet 8 inches from the ground.

The character of the weather was practically uniform during our stay at Sahdol. At night the minimum temperature was about 32° up to January 20, afterwards a little warmer (not falling below 39°, on January 23 and 24). At about 7.30 A.M., soon after sunrise, the temperature began to rise rapidly, attaining a maximum of about 80° at about 2 P.M., and remaining near this point from noon till about 4.30 P.M., when a fall nearly as sudden as the rise began. The air was nearly saturated with moisture at night and very dry in the daytime. There was heavy hoar frost at night.

These conditions seriously limited the time available for photography, which could only be carried on conveniently during the hot part of the day, say from 10 A.M. to 6 or 7 P.M., as there was no ready means of warming the water in the dark room.

The first clouds seen since the party landed in India were light fleecy clouds in the evening of Wednesday, January 19, and more appeared in the early mornings of January 20 and January 21, dispersing in each case between 10 and 11 A.M. The day of the eclipse was perfectly cloudless throughout, and the definition good.

[For detailed readings of thermometers and barometer, see separate Report by Professor Turner.]

8. *Instruments, &c.* [See separate Reports of the observers.]

9. *Huts.*—The chances of rain being so small, waterproof huts were not considered necessary, and the instruments were protected by rush thatchings laid on a framework of bamboo, which could be readily removed as required.

10. *Assistance.*—The observers were assisted in the exposures as below:—

The Astronomer Royal—

Mr. McA'Fee............	Recorded times of exposure.
Mr. Harold Christie	Exposed at objective.
Vishnoo Babaji Garud....	Handed plates.
Venayek Narayan	Received plates.

Professor Turner—

Dondu Venayek.........	Exposed at objective.
Tukaran Hanmant.......	Handed plates.
Shankar Devidas	Received plates.

Also

Govind Balwant Joshi....	Counted seconds aloud.
Narayan Vishnoo Apte....	

A few seconds before totality, as shown by the diminishing crescent of the sun, Professor Turner was to call "Get ready"; at totality to call sharply (the monosyllable "Tup" was used). The first time-

keeper immediately started the stop-watch and proceeded to count aloud "one, two, three," &c., up to sixty, when the second time-keeper took up the counting, "one, two, three," &c. By having two timekeepers, opportunity was given to both to see the eclipse.

The operations were rehearsed on every day of the week preceding the eclipse, at the time of totality, and on two days also at dusk, with lamps.

A photographic hut with a supply of chemicals was supplied from the Calcutta office of the Surveyor-General's Department, and Mr. George, of that department, was told off to assist in the photographic work. He developed some of the photographs taken by the Astronomer Royal during the partial phases.

11. *The Day of the Eclipse.*—Perfectly clear throughout. The morning was spent in final preparations. The first contact occurred at 0 hr. 13·3 mins. local mean time, and the Astronomer Royal proceeded to take nine photographs of the partial phase, the first being exposed at 0 hr. 14·6 mins., and the last at 1 hr. 22·2 mins. Totality commenced at 1 hr. 41·1 mins., and lasted about 105 seconds, during which time the programmes detailed below were successfully carried out. Nine more partial phase photographs were taken between 1 hr. 59·4 mins. and 2 hrs. 59·2 mins. The fourth contact was at 3 hrs. 1·6 mins. (see accurate times below).

There was a good deal of light during totality, and lamps were not in any way needed. The temperature fell 4·5° between first and second contacts, and another 3·5° between second contact and 2 hrs. It had practically returned to its normal value by the fourth contact (see accurate readings below). But the fall of temperature did not nearly represent the sensation of chill. At 1.15, when the air felt distinctly chilly, the temperature had only fallen 2°.

There was no appreciable "shadow" effect at totality, nor was any such effect noticed by two observers (General Woodthorpe, R.E., and Colonel Sir T. Holditch, R.E.) from the top of a hill a few miles away, close to the central line. These observers did, however, notice the well known "shadow bands" on the table they had prepared for sketching, without having previously heard of these bands in any way.

We had not many opportunities of observing the behaviour of animals. Kites which had been circling round the camp flew off to the surrounding trees some minutes before totality, and about the same time we heard cries from the village of Sahdol. We were told by another observer (Professor E. G. Hill, of Allahabad) that at Buxar he had noticed a herd of goats get into line and march homewards; that two mongooses in a hole in a bank had seemed very much frightened; that squirrels were silent during totality, and that a kingfisher began catching fish.

PART II.—SEPARATE REPORT BY MR. W. H. M. CHRISTIE.

The programme of observation was composed of two distinct parts—(1) Photographs of the corona on a large scale during totality; (2) photographs of the partial phase before and after totality for determination of the position of the moon relatively to the sun.

The instrument used in both cases was the photographic telescope by Grubb, with object-glass of 9 inches aperture and 8 ft. 6 in. focal length (presented to the Royal Observatory by Sir Henry Thompson), to which a concave compound lens by Dallmeyer, of 3 inches diameter and 12 inches focus, had been fitted as a secondary magnifier, placed a short distance within the focus. This combination gave an image of the sun 4 inches in diameter, and a field (for full pencils) of nearly 10 inches diameter, so that the corona to a distance of one and a half radii from the Sun's limb would be included in the field. A cœlostat, specially designed by Dr. Common, carrying a plane silver-on-glass mirror of 16 inches diameter, made by him, was employed to reflect the rays into the Thompson coronagraph, which was firmly mounted on two brick piers, so as to point to the mirror at an angle of depression of about 10°, and to be placed in an azimuth of about 17° north of west for the day of the eclipse. The camera was furnished with eight plateholders, taking 12×10 in. plates, seven being reserved for use during totality, and the eighth fitted with a Thornton-Pickard instantaneous focal-plane shutter, to take photographs on $8\frac{1}{2} \times 6\frac{1}{2}$ in. plates during the partial phases, for determination of the moon's position.

The seven slides for photographs of the corona during totality were exposed as below, the exposures being given with a screen held

No.	Exposure. Beginning.	End.	Duration.	Plate.	Developer.
	Secs.	Secs.	Secs.		
1	6	7	1	Ilford ordinary..........	Hydroquinone dilute.
2	12	17	5	Ilford rapid.............	,, ,,
3	24	34	10	,, ,, (backed)......	,, ,,
4	40	60	20	Rocket (backed)..........	,, ,,
5	67	75	8	,, ...	Eikonogen.
6	81	82	⅓	Ilford ordinary	Hydroquinone dilute.
7	89	91	2	Gazelle (dry collodion).....	,, ,,

in front of the object-glass by my son Harold, and the times, reckoned from the commencement of totality (2nd contact), being recorded by Mr. McA'Fee, of the Indian Survey Department.

It had been intended to use Hill-Norris dry collodion "Gazelle" plates for three of the slides (the fineness of grain as compared with gelatine plates giving them a marked advantage), but from trials made before the eclipse it was found that these plates were for some reason untrustworthy. I, however, thought it well to expose one of these plates, but the result is not satisfactory.

The sky was cloudless during the eclipse, and the programme was carried out without a hitch, with the aid of two native assistants of the Survey Department (Mr. V. B. Garnd and Mr. V. Narayen), who respectively handed me the slides and received them from me, and there was fifteen seconds to spare before the end of totality, the duration at Sahdol being 1 min. 45½ secs. as observed.

For the partial phase, nine photographs were taken between first and second contacts, and eight between third and fourth contacts, as well as a photograph for orientation (with double exposure) immediately before and after the eclipse. The aperture of the object-glass was reduced to 3 inches for these photographs, as it was found by trials before the eclipse that with the aperture thus reduced the exposure given by the Thornton-Pickard shutter set to its highest speed was satisfactory for the slow plates used (Thomas's lantern plates). The times of exposure were recorded on a chronograph, a key being pressed by me in the left hand at the same instant as the exposure was given by pressing a pneumatic ball in the right hand. The times of the fall of the shutter were also independently recorded by Mr. McA'Fee with a chronometer carefully compared with the transit-clock. All the arrangements for accurate local time, which was of vital importance for this part of the programme, and for determination of the longitude of the station by connection with the principal triangulation of the Survey of India, were most ably carried out by Major Burrard, R.E., and Lieut. Crosthwait, R.E. The position of my instrument, as found by them after the eclipse, was Long. $81^\circ\ 21'\ 33'' = 5^h\ 25^m\ 26^s{\cdot}2$ E., Lat. $23^\circ\ 16'\ 45{\cdot}3''$ N. Altitude above sea-level 1502·4 feet.

The coronagraph was carefully focussed before the eclipse by use of the method described in the Report of the Eclipse Expedition to Japan, 1896,* the image of an object (gauze net in the plane of the plate), being photographed by reflection normally from the plane mirror of the cœlostat. A special spare back for the plateholder was prepared with a hole covered with gauze net just above the centre, and one of the 12 × 10 in. plates being cut in two, one half was placed in the lower half of the plateholder and the reflected image photo-

* 'Monthly Notices,' R.A.S., vol. 57, p. 105.

graphed on it at different parts of the field, the source of light being a paraffin lantern. The adjustment to focus was made by moving the secondary magnifier, rings of paper placed between flanges on the adapter carrying the magnifier and its mounting giving the means of doing this with great nicety. By this method, in which the error from imperfect focus is doubled by the double passage of the rays through the telescope, it was found that a displacement of the magnifier through the thickness of a sheet of paper (0·005 inch), representing 1/20,000th part of the focal length, made a sensible difference. The focus was thus obtained with great accuracy, as is evidenced by the sharpness of the image on the photographs taken during the partial phase.

The photographs with exposures of 8 secs., 10 secs., and 20 secs. all show coronal structure up to the edge of the plate, the streamer in the S.W. being particularly bright. A hurried eye estimation made by me during the 20 seconds' exposure gave the extreme extension of this streamer as about two-thirds of the distance of Venus from the Sun's centre, or about $3\frac{1}{2}°$ from the limb. The field being necessarily limited by the diameter of the concave enlarging lens (3 in.), it would be desirable to have one made of larger diameter for future eclipses so as to allow of the use of larger plates.

A comparison of the whole series of photographs indicates a close correspondence between the coronal streamers and the prominences visible, this correspondence being particularly striking in the case of three prominences in the N.W. quadrant from which three coronal rays rise, arching over at a distance of about 7′ from the limb and uniting to form one component of the striking long double ray in that quadrant. Other prominences on the Sun's limb appear also to be associated with extensions of the corona. The form of the corona bore a closer general resemblance to those of 1886 and 1896 as photographed than would have been expected considering that the date of the eclipse was so much nearer the epoch of minimum sun-spots, and in this connection it may be noted that there were three important groups of spots on the Sun about the time of the eclipse, and that a series of magnetic disturbances of moderate amount were recorded at Greenwich just prior to the eclipse, from January 15 to 21 continuously, indicating an unusual state of magnetic activity in close correspondence with the solar activity as evidenced by the Sun spots.

Part III.—Separate Report by Professor Turner.

Instrumental Equipment.

1. *The Camera.*—The double camera used in the Fundium Expedition of 1893 by Sergeant Kearney, and taken out to Japan in 1896 without result. The tube is of wood, 6 feet long and 14 × 7 inches in section, divided by a partition into two tubes of 7 × 7 inches section. In one of these is placed the "Abney"* lens of 4-inch aperture and 62-inch focal length, giving an image of the sun 0·57 inch in diameter; in the other the photoheliograph objective No. 2 (used in *Transit of Venus* expeditions), of 4-inch aperture and 5-feet focal length, with a Dallmeyer secondary magnifier of 7½ inches focus placed 5 inches within the focus, and giving an image of the sun 1½ inches in diameter; the camera furnished with six plate-holders, each taking two plates of 160 × 160 mm. (as in use for the Astrographic Chart), both plates being exposed by a quarter-turn of one shutter.

2. *The Cœlostat.*—The camera was pointed to a 16-inch cœlostat, the mirror of which was made by Dr. Common, the mounting and clock by Mr. J. Hammersley from designs by Dr. Common.

3. *The Polariscope.*—On the tube, and pointing to the same cœlostat, was a polariscopic apparatus consisting of an ordinary slit spectroscope (and telescope), with an Iceland spar double image rhomb substituted for the ordinary prisms. The instrument in its normal state had been used by Mr. Maunder in the 1886 eclipse expedition for photographing the spectrum of the corona. It is fitted with two plate-holders. The dimensions are as follow:—

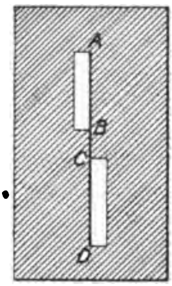
Objective......	3½ inches aperture,	18 inches focal length.
Collimator.....	1½ ,, ,,	6½ ,, ,,
Camera........	2 ,, ,,	9 ,, ,,

The use of the apparatus will be understood from the analogy of the ordinary spectroscope, regarding the Iceland spar rhomb as a prism giving only two colours—the two kinds of polarised light. We can thus use a wide slit, opening it until the two images of the slit are just in contact without overlap. This was found to happen with the apparatus in use with a slit of width 0·19 inch. The

* One-half of a doublet photographic lens by Dallmeyer, belonging to Captain Abney, used in the Eclipse Expeditions of 1886, 1887, 1889, 1893, and 1896, acquired from him by the Royal Astronomical Society in 1893 for permanent use in eclipse expeditions, in consideration of their replacement by two others.

diameter of the sun's image thrown on the slit being 0·21 inch, it was thought best to take the two photographs, so as to include opposite limbs of the eclipsed sun, and as much of the corona as could be got. The change from one portion of the sun to another was arranged by having two slits as follows:—

The two slits were cut in a piece of blackened card, the actual size of which is shown in the diagram. If the line ABCD had been diametral to the sun's or moon's image, half the moon and corona would in the first instance have appeared in the middle of the lower slit, CD. In this position the first exposure was given, producing on the plate two images side by side of the right limb of the eclipsed sun, one image being due to light polarised in a plane



parallel to CD, and the other to light polarised in the perpendicular plane. For the next exposure the card was slipped down in the groove in which it fitted lightly, and the left limb of the eclipsed sun fell on the middle of the slit AB; and so two images of the rest of the corona would be obtained. By combining the two photographs, we could get a double picture of a slice of the corona 1·0 inch long and 0·40 inch wide, containing the moon centrally; or, translating inches into diameters of the moon's image, five diameters long and two diameters wide. As a matter of fact, the image of the sun was not adjusted centrally on the line ABCD, and a good deal more of the moon's disc appeared on one photograph than on the other, this being deliberately arranged for a special reason, which will appear in discussing the photographs obtained.

Instrumental Adjustments.

5. *Adjustment of Cœlostat.*—The adjustment of the polar axis was made as described in the Report on the Japan Expedition* by means of the attached declination theodolites.

The following are the actual observations, those with the level

* 'Monthly Notices,' vol. 57, p. 102.

being made on the meridian, and compared with the known latitude so as to give the same sign to the errors as the sun observations:—

Date.	Sun's H.A.	Obs. decl.	Tab. decl.	O.—C.
Jan. 11....	−4·0	−21° 45′	−21° 50′	+5′
		Observation with level		+3
	(Adjusted in azimuth and altitude.)			
	−3·0	−21 50	−21 49	−1
		Observation with level		0
	−1·0	−21 49	−21 48	−1
Jan. 17....	−3·7	−20 47	−20 45	−2
		Observation with level		0

[These observations were made with a dummy axis, before the mirror and its cell were mounted on January 19.]

Jan. 21....	−3·0	Observation with level		+6

[Adjusted level: probably disturbed by the weight of the mirror and its cell.]

	−2·0	Observation with level		0
	−2·0	−19 54	−19 54	0

[As there seemed some vibration in the instrument, the end of the arc holding the mirror was supported by a wooden block driven tightly under it; this again altered the level, which was readjusted.]

	0·0	−19 51	−19 53	+2
	0·0	Observation with level		+2
	+2·0	−19 49	−19 52	+3
Jan. 22....	−4·5	−19 37	−19 42	+5
		Observation with level		+2
„ 23....	−1·0	−19 24	−19 26	+2
		Observation with level		+3

It will be seen that the introduction of the wooden block as a partial support to the cœlostat disturbed the adjustments slightly, but it did not seem advisable to attempt to correct these small errors, which would have been a troublesome process with the stress of the wooden block to consider. The block certainly deadened the vibrations.

6. *Tilt of Mirror.*—If the mirror is not parallel to the axis of rotation the image will not be quite stationary.* Both instruments were tested for this error by reversing the mirror and cell in the Y's and noting the consequent displacement of the sun's image on the ground glass in the focal plane of the telescopes. The displacement,

* 'Monthly Notices,' vol. 56, p. 417.

giving double the inclination of mirror to axis, was found by C. on January 19 to be 7·2′; and was corrected after several trials to be 0·8′, denoting an error of 0·4′. The correction was made by screwing a short screw, made for the purpose, into one of the holes at the back of the mirror cell. [There are three of these holes, into which long screws are screwed in the operation of inserting the mirror into its cell.] T.'s mirror was examined on the same day, and being found to be sensibly parallel to the axis, no correction was necessary.

7. *Focussing of Telescopes.*—The method adopted was that described in the Report on the Japan Expedition.* The telescope was pointed normally to the mirror, and the image of a bright point or object in the plane of the film was photographed on the film.

A glass plate being cut in two, one half was blackened with asphalte, and the word "astronomy" printed on it by scratching with a needle point. This was the object photographed in the following experiments. Gauges had been made in England by means of which the three lenses (the Abney lens, the photoheliograph lens, and the Dallmeyer enlarging lens) could be set very accurately to positions in the wooden tube giving good focus. Positions at definite distances from these could be obtained by unscrewing the object glasses through fractions of a turn. If positions were required *within* the gauge position, the object glass was first *pushed* in slightly; and then it was noted what fraction of a turn it must be unscrewed to bring it to the gauge-position. Designating the gauge-position by zero, and one turn out by +1·0, one turn inside by −1·0, the following positions were tried:—

Abney Lens.

Plate 1, January 16, 0·0, +0·5, +1·0 positions. Three images on same plate, 0·0 the best.

Plates 2—5 were devoted to experiments on illuminants. A candle was found most convenient after all.

Plate 6, January 16, 0·0, −1·0, −1·5 (+0·5) positions; (+0·5) not on plate? 0·0 the best, if exposures rightly identified.

Plate 7, January 16, −1·5, −0·5, +0·5 positions; −0·5 the best of these.

Plate 8 (January 16). To make sure pushed still further in.

The above differences were slight, −3·0, −2·0, −1·0 positions, −1·0 the best.

Hence on this day focus seems at −0·5, or very close to it.

* 'Monthly Notices,' vol. 57, p. 105.

Dallmeyer Lens and Enlarger.

Plate 9, January 16, −1·0, 0·0, +1·0, +2·0 positions; 0·0 the best.

Plate 10, January 16, −0·5, +0·5, +1·5 positions; +0·5 the best.

Plate 11, January 17, 0·0, +0·25, +0·5, +0·75, 0·0 positions. Both 0·0 exposures were worse than the others.

Of the others 0·25 was perhaps best near the centre, and 0 5 (or 0·75 ?) further from centre.

Hence 0·5 was adopted, *i.e.*, the object glass was screwed one-half turn out. The screw has 12 turns to the inch; and the focussing was thus correct to 0·02 inch, as far as could be judged.

Abney Lens—(continued).

Plate 12, January 17, −1·0, −0·5, 0·0, +0·5, +1·0 positions; −1·0 best; −0·5 very good; 0·0, +0·5, +1·0 distinctly inferior.

This contradicts nothing but plate 6, on which the exposures may be wrongly identified, and if on that plate 0·0 is missing instead of +0·5, then −1·0 would be the best on the plate. *Hence* −1·0 *was adopted.*

[At 25 turns to the inch this focus was also correct to 0·02 inch.]

8. *Programme of Observations.*—The six slides for photographs of the corona were filled as below, the same plates being used for the Dallmeyer and Abney lenses in each case, and standard squares having been impressed on plates 2, 4, 5, 6, by Captain Hills, R.E, before sending the plates out from England.

No. of slide.	Exposure.	Plate.
1	1 sec.	Dry collodion "Gazelle."
2	5 secs.	Ilford "Empress."
3	10 "	Rocket.
4	20 "	Ilford "Rapid."
5	1 sec.	Ilford "Empress."
6	2 secs.	Ilford "Empress."

Besides these the two exposures through the polariscopic apparatus were made, each of 5 seconds' duration, Paget plates being used.

The developer used was amidol for all these plates, which were all successfully exposed.

9. *Times of Contacts.*—These were independently observed by Professor Turner and by Major Burrard, R.E. The former used for first and fourth contacts a pocket watch which was compared with the sidereal clock at 8.5 A.M. and found 29 seconds fast; and again at 8 P.M., and found 26·9 seconds fast, of local mean time. At second and third contacts he gave a sharp signal, the time of which was

noted by Mr. McA'Fee on a mean time chronometer, carefully compared with the clock both before and after. The contacts were observed by throwing a 4-inch image of the sun on white paper from a navy-pattern telescope. [Aperture 2 inches, focal length 28 inches, magnifying power of negative eyepiece 25.]

Major Burrard observed with a 2-inch telescope, and recorded his times on the chronograph in connection with the sidereal clock.

This clock was in a grass hut and subjected to a daily variation of 50° of temperature, but great care was taken with the star observations, as will be explained in detail in the final report of the Astronomer Royal. The local mean times of the star observations for clock error (by Major Burrard) were

January 21 days 18 hrs. 30 mins. 58 secs., and January 22 days 7 hrs. 21 mins. 13 secs, and the errors of the clock at these times were, +0 min. 12·83 secs. and +0 min. 14·88 secs. respectively.

Local Mean Times of the Four Contacts.

	Observer H.T.			Observer B.	Calculated time.	Calculated from 'N.A. Circular, No. 16,' with formulæ for	
						Nagpur.	Benares.
	hrs.	mins.	secs.	secs.	secs.	secs.	secs.
I.	0	13	11·7	22·8	6·3	11·3	8·8
II.	1	41	3·0	3·3	5·4	12·3	9·3
III.	1	42	48·5	47·9	52·0	67·3	49·3
IV.	3	1	40·2	35·7	51·3	63·7	45·3

10. *Remarks on Formulæ for Prediction of Contacts.*—As was mentioned in paragraph 5 of the joint report of the Astronomer Royal and Professor Turner, the data for predicting the four contacts were found insufficient. This will be seen by comparison of the last two columns, wherein the times as given by the published formulæ most nearly suitable for Sahdol are given. On application to the Superintendent of the 'Nautical Almanac,' he kindly supplied the data for the third column, giving the G.M.T.s of the four contacts, to which the longitude of Sahdol has been applied.

[The position of Sahdol is

5 hrs. 25 mins. 26·2 secs. E., Lat. 23° 16′ 45″ N.]

As his letter contains a suggestion which may be useful to other observers, I reproduce it here.

"Nautical Almanac Office,
"March 26, 1898.

"Dear Turner,

"You will find the deduction of the formulæ (used in 'N.A. Circular No. 16' and others) in appendix to N.A. 1836, p. 117. These equations will give sensible accuracy for a distance of about 50 miles from the point for which they are computed. In this case the distance is about 150 miles.

"I find that the most expeditious way of getting accurate results in this work, is to use the Besselian Elements (page 4 of circular No. 16). You can infer the time of middle of eclipse to the nearest minute from the Table on p. 3 of circular, and then 10 minutes work gives you the times of beginning and ending of totality with sensible accuracy.

"Of course for accurate determinations of times of first and last contacts (partial phase) special computations for the approximate times of these contacts would be necessary.

"Yours very truly,
"A. M. W. Downing."

The following remarks on the geometrical significance of these formulæ may not be out of place.

The time of a contact t at a place of geocentric latitude l and longitude λ is given by a pair of equations of this form

$$\cos \omega = A + B \sin l + C \cos l \cos (\lambda + D)$$

$$t = E + F \sin \omega + G \sin l + H \cos l \cos (\lambda + K).$$

Write these in the form

$$\cos \omega = A + L\{\sin l \sin l_0 + \cos l \cos l_0 \cos (\lambda - \lambda_0)\} = A + L \cos PP_0,$$

$$t = E + F \sin \omega + M\{\sin l \sin l_1 + \cos l \cos l_1 \cos (\lambda - \lambda_1)\}$$
$$= E + F \sin \omega + M \cos PP_1,$$

where P is the point (l, λ) and P_0 a point whose geocentric latitude and longitude are l_0 λ_0 given by the equations

$$C \tan l_0 = B = L \sin l_0, \qquad \lambda_0 + D = 0,$$

and PP_0 is the arc of the sphere between P and P_0.

Similarly for the point P_1.

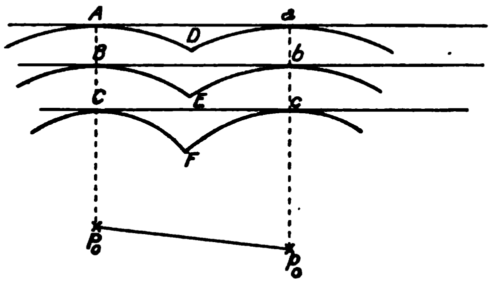
In the case of the second and third contacts, which determine totality, the equations only differ in the sign of F: so that the duration of totality is constant when ω is constant. The condition $\omega = 0$ gives us points for which the eclipse is just total for an instant, *i.e.*, the points on the borders of the totality belt. But from the equation

$$\cos \omega = A + L \cos PP_0$$

we see that ω is constant when the arc PP_0 is constant, *i.e.*, along the arc of a small circle described with centre P and radius PP_0.

The bounding lines of the totality belt given us by the approximate formulæ of the 'Nautical Almanac Circular,' are thus portions of small circles of the sphere.

Now, suppose we have formulæ given for the neighbourhoods of two points B and b on the central line; for which P_0 and p_0 are the centres of the approximate loci of equal totality. Then the approximate formulæ for B will give us as the northern boundary of the



totality zone the circular arc AD, touching the true line at A, but falling south of it elsewhere; and the approximate formulæ for b will give us the arc aD. Thus at the intermediate point D, both formulæ give errors in the same direction; and unless the points B and b are tolerably close together we cannot get a good prediction for intermediate points by simple interpolation.

The true lines Aa, Bb, Cc, are the *envelopes* of such circles as AD, BE, CF, as we travel along the central line, P_0 travelling along the path P_0p_0 in correspondence.

It is to be noted further, that the approximate formulæ give a constant duration of totality along the line BE, which is the approximate central line (given by $\sin\omega = 1$): whereas the duration generally changes as we go east or west. But interpolation between results for B and b would probably give the means of allowing for this change.

If instead of the duration of totality, we take the time of one of the contacts, the approximate loci are no longer circles, but curves of the form

$$(a+b\cos PP_0)^2+(c+d\cos PP_1)^2=1,$$

and the geometry is less simple; but these curves will have the true line for their envelope just as the circles did.

Now, if the contact of the circles or the curves with their envelope is of the *second order* interpolation becomes possible, for the circles cross the envelope and thus the error introduced is + to the east

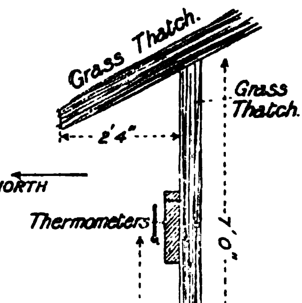
and — to the west. The test of this is to calculate the contacts for b with the constants given for B, and compare with true values for b; similarly calculate the contacts for B with the constants given for b and compare with the true values for B. If the errors are of opposite signs, then the curve crosses the envelope, and the contact is of the second order. A few experimental calculations of this kind, with the data of 'N.A. Circular, No. 16' seem to show, however, that the contact is not generally of the second order, and the approximations are thus subject to the disadvantages above indicated.

11. *Meteorological Observations.*—Lieut. Crosthwait, R.E., has kindly supplied the following particulars of the meteorological observations:—

They were made from 1898, January 14, to January 24 inclusive, by the following observers:—

Venayek Narayan, Narayan Vishnoo Apte, Govind Ramchandra Bhabhi, and Vishnoo Babaji Garud.

The thermometers were attached to a board suspended to the north side of a grass hut, with an overhanging roof, completely shading them from the sun's rays at all times of the day. Height above ground and other dimensions shown in accompanying diagram.



The situation is open, facing towards the north, on a gently undulating plain, about 1500 feet above sea level. The only hills in the neighbourhood are from 2000—3000 feet high, distant about 12 miles.

The following instruments were used: A maximum and minimum thermometer No. 20,443 by Hicks; a wet and dry bulb No. 38,037 by Negretti and Zambra; a mountain mercurial barometer, standing on a tripod, No. 1824 by L. Casella.

Before beginning, the following comparisons were made with a standard thermometer No. 93,638 by Casella :—

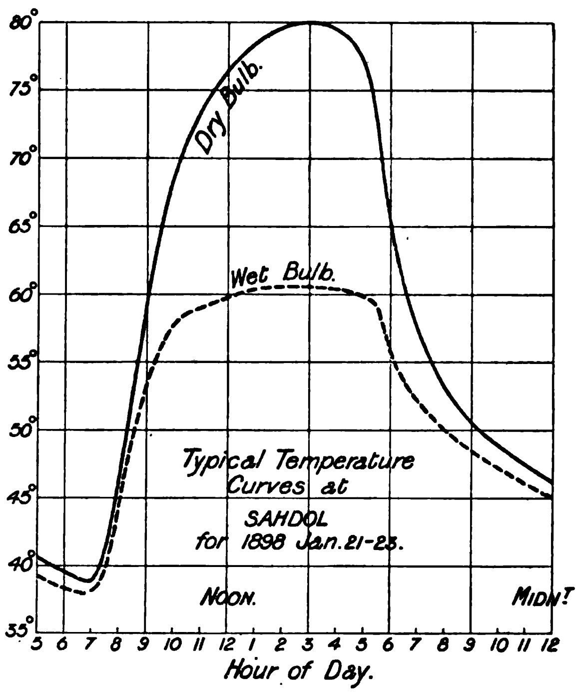
Standard read	78·6°		
Dry bulb "	77·9	correction	+0·7°
Wet " "	78·0	"	+0·6
Maximum "	78·0	"	+2·6
Minimum "	78·0	"	+0·6

The wet and dry bulb thermometers, and the barometer with its attached thermometer, were read every half hour from 5 A.M. till 8 P.M. or later. The maximum thermometer was read at 4 P.M., the minimum at 10 A.M.

On the day of the eclipse, observations were made of wet and dry bulb and barometer, and also of the standard thermometer (Casella No. 93,638) every five minutes.

The barometer was very steady throughout our stay, near 28·6 in. ; and it seems scarcely necessary to publish the details.

The wet and dry bulbs both followed very closely the curves shown in the attached diagram, the deviations from the curve seldom exceeding a degree or two. To avoid needless printing, the follow-



ing particulars for a number of readings on January 21, 22 and 23 are given as illustrations:—

Excess of Readings of Thermometers over the Typical Curves shown in the Diagram.

Hour.	Dry bulb. Jan. 21.	Jan. 22.	Jan. 23.	Wet bulb. Jan. 21.	Jan. 22.	Jan. 23.
6 A.M.	−1·9°	−1·3°	+1·1°	−1·6°	−0·6°	+0·8°
8 "	−1·4	+0·5	+2·0	−1·8	−0·3	+1·8
10 "	−1·5	+1·5	+2·8	−0·8	−0·6	+1·1
NOON	−2·6	+1·3	+1·9	−0·8	+0·2	+0·8
1 P.M.	−1·6	0·0	+2·0	−1·9	−1·0	+2·1
2 "	−0·8	−9·0	+1·0	−1·6	−3·5	+1·5
4 "	−0·6	−2·6	+0·4	−0·3	−0·5	+1·5
6 "	+3·0	−2·3	+1·1	+0·2	−0·6	−0·9
8 "	−1·6	−0·6	+2·0	−1·6	+0·1	+1·8
10 "	−1·9	+0·3	+2·3	−0·8	+0·6	+1·8

[The anomalous readings of dry bulb at 6 P.M. on January 21, and of wet bulb at 6 P.M. on January 23, are apparently not mistakes, unless the neighbouring observations are similarly affected.]

We may thus take it that the typical curves of the diagram represent with considerable accuracy what would have been the state of things on January 22, if the eclipse had not taken place.

Comparing then the readings during the eclipse with this curve, we get the following differences, which may be regarded as the effect of the eclipse.

Effect of the Eclipse on Temperature as shown by Five-Minute Readings.

Time of day. hrs.	mins.	Dry bulb.	Wet bulb.
0	0 (NOON)	+1·2°	−0·1°
0	5	0·0	−0·7
0	10	+0·8	−0·2
0	15 First contact	+1·7	+0·2
0	20	+1·5	+0·1
0	25	+0·8	−0·9
0	30	+0·6	−0·5
0	35	+0·4	0·0
0	40	+0·3	−0·1
0	45	+0·2	−0·1
0	50	−0·5	−0·2
0	55	−0·6	−0·4

Effect of the Eclipse on Temperature as shown by Five-Minute Readings—*continued.*

Time of day. hrs.	mins.		Dry bulb.	Wet bulb.
1	0		−1·3	−0·8
1	5		−1·9	−0·8
1	10		−2·0	−1·3
1	15		−2·2	−1·4
1	20		−2·8	−1·9
1	25		−3·4	−1·9
1	30		−4·0	−2·5
1	35		−4·0	−2·5
1	40	Totality	−5·1	−3·5
1	45		−7·2	−3·5
1	50		−7·7	−3·5
1	55		−8·3	−3·6
2	0		−8·9	−3·6
2	5		−8·5	−3·1
2	10		−7·6	−2·6
2	15		−6·7	−2·2
2	20		−5·7	−1·9
2	25		−5·1	−1·7
2	30		−4·4	−1·7
2	35		−3·4	−1·5
2	40		−3·7	−1·4
2	45		−3·5	−1·2
2	50		−3·5	−1·2
2	55		−3·1	−0·6
3	0	Last contact	−3·1	−0·6
3	30		−2·6	−0·3
4	0		−2·5	−0·2

"Total Solar Eclipse of January 22, 1898. Preliminary Report on Observations made at Ghoglee, Central Provinces." By Professor RALPH COPELAND, Astronomer Royal for Scotland. Received May 10, 1898.

In the month of August, 1897, I was invited by the Joint Permanent Eclipse Committee to take part in observing the total solar eclipse which occurred in India on 22nd January of the present year.

The preparation of the equipment, which will be described further on, was at once proceeded with, and by the sanction of the University authorities and the Secretary for Scotland I was granted the

necessary leave of absence from the University and the Royal Observatory.

Having shared in the general disappointment of the Russian eclipse of 1887, and the no less unfortunate visit to Vadsö in 1896, I resolved on this occasion to occupy a separate station at some distance from any large group of observers. My only companion was our observatory engineer (James McPherson), who on the two previous occasions had shown his skill and energy in setting up and handling the instruments.

A grant of £180 was made to me by the Committee. This would have been amply sufficient had I dispensed with the services of Engineer McPherson, but without his aid I could not have carried out my plan of occupying an independent station and using several instruments.

Our equipment consisted of—

(1) A horizontal telescope of 38 feet focus and 4 inches aperture to be used with a fixed mirror, the image being received on 18-inch plates moved by clockwork. This instrument was provided with a direct vision prism mounted on a slide in front of the object-glass, which, when drawn into position by an attendant, transformed the telescope into a prismatic camera.

(2) A small prismatic camera designed for the investigation of the ultra-violet rays of the solar appendages. To this end the object-glass was of quartz and Iceland spar, the prism being of the latter material.

(3) A slit spectroscope by Grubb, with one compound prism. (2) and (3) were carried by a 4-inch equatorial mounting, and served to balance each other.

(4) A 4-inch camera with a doublet lens, by Dallmeyer, of 33-inch focus, mounted on a 3-inch equatorial stand. Both the equatorial mountings were fitted with driving clocks.

In place of a hut we were provided with a supply of laths, boards, and brown paper, plain as well as waterproof and blackened, for building the camera of the 40-foot, which had also to serve as a dark room. The hut built with these materials served the intended purpose satisfactorily. It was ventilated by a tin chimney like that of a magic lantern.

The instruments were despatched on the 20th November, *viâ* Leith and London, to Bombay. Engineer McPherson left Edinburgh on the 2nd December to embark in London on board the P. and O. s.s. "Britannia," while I, leaving on the 8th, was able to catch the same steamer at Brindisi on the 12th December. Bombay was reached on the 26th December, and Nagpur, in the Central Provinces, two days later. Here we were most hospitably received by Colonel Henry J. Lugard (Madras Staff Corps), and with his help

and that of his son, Mr. Edward Lugard, Executive Engineer, Bhundara, a station was finally selected on the last day of the year, close to the village of Ghoglee, 16 miles north-west of Nagpur, and about 2 statute miles south-east of the line of central eclipse. On New Year's Day I observed the sun for latitude, time and azimuth, and on the 2nd January we began our camp life, having lived meanwhile at Kalmeshwar, in a bungalow belonging to the Department of Works, three miles distant, on the way to Nagpur. We found the large double tent provided by the Government most comfortable. It was pitched beside a grove of mango trees, under which was a large well with a plentiful supply of water. On the 4th January concrete foundations were begun for the fixed mirror and lens, for the plate-carrier of the long-focus telescope, and for each of the two equatorials. The latter were placed in line with the dark room of the horizontal tube, so as to bring the observers within earshot of the metronome which was used to regulate the lengths of the exposures. It is needless to give particulars respecting the adjustments of the equatorials, which were considered sufficiently accurate when within two minutes of arc of the truth.

The method pursued with the horizontal telescope was as follows :— With the theodolite placed on the proposed centre line of the tube, the azimuth of a distant tree was found from observations of the sun, and also of the pole star. Two sets of footholes for the theodolite were made in blocks of cement at different levels, but referred to a common centre. By this means the theodolite could be used either as a collimator looking through the lens of the long telescope, or as a directing telescope to bring the tube, lens, and plateholder exactly into the required line. The fixed mirror was roughly adjusted as regards azimuth with the theodolite and a reflecting eyepiece, and as to inclination by means of a gauge and spirit level. The final adjustment was given by slightly turning the slow motion screws of the mirror until the sun's image ran along a parallel of declination drawn on the cover of the plate-holder, and also crossed one or other of a set of vertical lines at a given computed time. The tube being set exactly horizontal, the plate-holder was "squared on" by viewing the image of the object glass in a mirror held against the plate-holder in reversed positions. The long-focus object glass was "squared on" with the help of one of the little centering telescopes originally designed by Fraunhofer. The inclination of the slide on which the plate-holder ran was found from the computed altitude and azimuth of the sun's centre two minutes before and two minutes after mid-totality. The same data also gave the speed at which the plate had to move—in our case 1·872 inch per minute. No provision was made to counteract the very slight effect of the rotation of the sun's image during the period of exposure. The

sliding frame was drawn forward by a wire cord and weight, the rate of motion being regulated by the speed at which the driving clock "payed out" the cord. A tendency to advance by jerks was altogether removed by thoroughly strengthening the clock seat-board and its attachment to the fixed frame. The clock, kindly lent by Lord McLaren, was made by Sir Howard Grubb. We utilised the slide motion to obtain a chronographic record of the exposures. Three pencils, in holders hinged to the standing part and moved by strings, marked the time on a slip of paper pasted on the back of the moveable frame.

The distance of the plate-holder from the cell of the lens had been found in Edinburgh to be 455·27 inches. This interval was set off in India with light wooden rods, which were compared with a Chesterman steel foot-rule. The photographic focus of the Dallmeyer 4-inch had been found to agree exactly with the visual focus. The instrument was focussed in India with the help of a focussing glass, both in the day-time on an object at a distance of 440 yards, and on stars at night, in the former case making allowance for the divergence of the rays by means of the well-known formula for conjugate foci. The two results were practically identical, but differed considerably from the scale reading used at home, owing to the shrinking of the wooden tube, in which the grain runs crosswise. The tube of the Iceland spar camera, being made of well-seasoned teak, was found unchanged in length, as proved by the linear spectra of Sirius and γ Argûs.

The greatest difficulty was experienced in filling the plate-holders of the long-focus telescope. It was only after many hours spent in paring and rasping the twisted frames that the plates were adjusted and ready for exposure. Two plates were broken in the process.

Our programme was as follows:—Eight plates, 18 inches square, to be exposed by Engineer McPherson standing in the dark room, where he had control of the cord for opening the spring shutter, were provided for the horizontal telescope, each carried in a separate holder. The prism was to be pulled into position by our native butler, Vardhya, at a signal from McPherson.

Mr. Meehan, Assistant Engineer of the Public Works Department, had kindly volunteered to work the Dallmeyer camera. He was provided with nine quarter plates, mounted in three long slides. The shutter was of the ordinary pneumatic kind.

I took charge of the ultra-violet prismatic camera, with six plates in three reversible holders. I had also one plate (Cadett) in the Grubb spectroscope, which was to be exposed by simply drawing back the slide. Cadett plates were used for the horizontal telescope and the 4-inch, while partly Lumière and partly Cadett plates were to be tried in the prismatic camera.

Mr. Meehan came in good time on the morning of the 22nd in order to have a final opportunity of practising the management of the 4-inch. Everything being prepared to the best of our ability, I anxiously watched with the finder of the prismatic camera for the first contact. The first indentation in the sun's limb was not perceived until 11 secs. after the computed time, but as the telescope only magnified thirteen times, and there was a chance that the prediction might be slightly wrong, this agreement was considered satisfactory. Ten minutes before the beginning of totality the observers took their assigned stations, and a little later the metronome was set going 2 mins. 14·6 secs. before the computed total phase, McPherson saw the following edge of the diminishing sun's image exactly on the line which had been previously marked on the sliding frame. 20 secs. later he started the clock in accordance with a signal given by me, and after about a quarter of a minute had elapsed each observer made a mark on the chronograph slip in response to the measured "one, two, three," called out by me in time with the beats of the chronometer. From this moment, which was 40·8 secs. before the computed disappearance of the sun, I watched the shortening line of light with the finder. It seemed a long time in disappearing, but the sunshade was so dark that I felt sure that nothing but the photosphere could be seen through it. I therefore refrained from giving any signal until the last trace of light had disappeared. I then called out "totality," as previously arranged, and had the satisfaction of hearing the shutter of the 38-foot (which made a rather loud noise) closing at the end of McPherson's first exposure.

The whole of the eight plates were successfully exposed in the horizontal telescope.

	Exposure.	Object.
No. 1	1·4 secs.	Corona.
2	6·7 „	Corona.
3	3·8 „	Spectrum.
4	6·7 „	Spectrum.
5	9·5 „	Corona.
6	13·2 „	Corona.
7	5·4 „	Corona.
8	1·0 sec.	Spectrum.

The five photographs of the corona are much disfigured by an exhalation thrown off by the bass wood of which the plate-holders are made, which has caused the grain of the wood to print itself in broad streaks on the pictures. By combining the various negatives in one drawing, however, there is reason to believe that the details of the brighter parts of the corona can be satisfactorily worked out. Plates 3 and 4 show very distinct spectral images

of the prominences corresponding to a number of lines in the violet region of the spectrum. On the last plate, which was exposed very shortly after the end of totality, there is a broad spectral band full of bright and dark lines of varying intensities, corresponding to irregularities in the sun's limb and the presence or absence of prominences. Many of the bright lines run out into the cusps. The scale of this photograph is such that H and K are 10 mm. apart. By an oversight the prism was not used with Plates 1 and 2 as was originally intended.

Mr. Meehan also exposed the whole of the nine plates allotted to him. Three of these show the coronal rays during totality. The fourth has the coronal streamers quite distinct, although the sun is already reappearing with a trace of Baily's heads. The fifth plate, taken several seconds later, shows the solar crescent still further disclosed, but with the whole of the moon's disc distinctly outlined against the background of corona. In the last plate there is nothing to be made out beyond the over-exposed solar crescent; the remaining three plates are blank. I am under great obligation to Mr. Meehan for his valuable assistance with this instrument, as well as for help in other directions.

In the small prismatic camera four plates proved to be as many as I could dispose of. The actual exposures attempted were 2·5 secs., 4·7 secs., 19·6 secs., and 14·0 secs. respectively. The resulting negatives show numerous rings and lines ranging from 1474 K to about W.L. 3000. The lines are sharpest in the first plate, while the 1474 K ring comes out more fully in the second and fourth negatives. The third plate is unfortunately blank.

The plate in the integrating spectroscope, which was used without a condensing lens, shows a spectrum of three strong bright lines with a number of feebler ones between them. With an exposure of about a minute, terminating just before the end of totality, the plate is decidedly under-exposed.

The makeshift chronograph, while working well for the other two observers, failed to record Mr. Meehan's signals distinctly, owing probably to the greater length of the cord required to reach his telescope.

On Wednesday, 26th January, we broke up our camp at Ghoglee and sailed from Bombay on the 29th, reaching Edinburgh on the 21st February.

I wish here to record my indebtedness to all the officials and private individuals, British and native, by whose kind aid the object of the expedition was so much furthered and our visit to Central India made so pleasant as well as scientifically interesting.

"Total Eclipse of the Sun, January 22, 1898. Preliminary Account of the Observations made by the Eclipse Expedition and the Officers and Men of H.M.S. 'Melpomene,' at Viziadrug." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received March 28, 1898.

LOCAL ARRANGEMENTS.

After various inquiries which I had made respecting the suitability of Viziadrug for observations of the total eclipse, I informed the Eclipse Committee that I was prepared to take charge of an expedition to that locality, and it was agreed that the observations at this station should be placed in my charge.

The latitude and longitude of the part of the fort at Viziadrug finally occupied were 16° 33′ 26″ N. and 73° 18′ 58″ E. respectively, and the duration of totality was estimated at 127 seconds.

In connection with the work at this station the Admiralty was asked for a ship of war to convey the observers from Colombo to Viziadrug, and to permit the use of the ship, if possible, as a base, to enable me to repeat the observations attempted in Norway in 1896 with the assistance of H.M.S. "Volage," which ship supplied twenty-four assistants during the eclipse and fifty volunteers for general observations.* As a result of the Royal Society's application, H.M.S. "Melpomene," in command of Captain Chisholm Batten, R.N., was told off to join the expedition.

The expedition, which left England on December 10, consisted of Mr. A. Fowler, Dr. W. J. S. Lockyer, and myself, together with the Marquis of Graham, who joined as a volunteer. Some little time after reaching Viziadrug Professor Pedler, F.R.S., joined the party from Calcutta, and shortly before the eclipse Mr. John Eliot, Meteorological Reporter to the Government of India, joined from Simla. On arrival at Colombo we found H.M.S. "Melpomene" waiting there, and at once proceeded to the selected spot of observation—Viziadrug.

During the three days' voyage to our station a call for volunteers was made by Captain Batten, and 120 came forward. Lectures and demonstrations were therefore at once commenced by Lieutenants Blackett, Colbeck, and Dugmore, second engineer Mountfield, and myself to the several parties of men who had undertaken to perform special pieces of work. Twenty-two separate groups of observers were formed. On our arrival at Viziadrug we were received very kindly by Mr. Bomanji, the collector of Ratnagiri, and an Overseer of the Public Works Department, who was on the spot in charge of

* 'Phil. Trans.,' A, vol. 190 (1897), pp. 1—21.

some most excellent masons and carpenters, picked men from Ratnagiri as we later ascertained, and plenty of material for the construction of the necessary concrete bases and huts. It was important to erect the huts as soon as possible, not only to shelter the instruments but the observers from the sun. Several screens were made which could be moved and placed in any required position; these were found to be invaluable while the instruments were being erected. A considerable number of coolies was also present to do such work as carrying packing-cases, sawing wood, clearing the camp, &c.

In the fort was also a police guard sent from Ratnagiri. The camp was watched both by day and night so effectively by them that no damage to any instrument was reported.

On the arrival of the "Melpomene" at Viziadrug, Mr. Bomanji came on board to report the arrangements which had been made for the expedition by the Government of India. As these were not quite completed, it was necessary for the first few days to return to the ship every evening, but afterwards Mr. Fowler, Dr. Lockyer, and myself took up our quarters at the Dak bungalow inside the Fort, close to the instruments. Meals were provided at the Collector's camp, which was also inside the Fort.

A party was landed at the fort on the afternoon of our arrival to inspect the site suggested by Mr. Bomanji, and it was at once evident that it would satisfy all requirements, provided the fluctuations of temperature of the great masses of masonry composing the fort had no disturbing influence on the steadiness of the air. In order to investigate this point a $3\frac{3}{4}$-inch telescope was erected, and observations of the surrounding landscape, and, at dusk, of various stars, were made, from which it appeared that the atmosphere was sufficiently steady for the observations.

Next morning the instruments were landed and the concrete bases for them were commenced. The erection of the huts was also begun by the native workmen and continued without intermission.

The instruments were set up as soon as their bases were ready, and by the end of a week all were practically in readiness for the eclipse. Constant clear skies enabled all the adjustments to be made without difficulty.

During the week preceding the eclipse the adjustments were frequently tested, and a complete system of drills was established.

As the number of volunteers was so large I pointed out to Captain Batten, who had volunteered to aid in a special branch of the work, the importance of his taking charge of the whole camp and giving all the necessary orders for conducting the operations during the general rehearsals, and the eclipse itself. He eventually agreed to this, and the procedure and time signals were arranged between us.

The groups of observers were as follows :—

1. Time.
2. 6-inch prismatic camera.
3. 9-inch " "
4. Integrating spectroscope.
5. 6-inch equatorial.
6. Coronagraph.
7. Discs.
8. Sketches of corona without discs.
9. $3\frac{3}{4}$-inch equatorial.
10. Observations on stars.
11. Shadow-bands.
12. Meteorological observations.
13. Hand spectroscopes.
14. Prisms for rings.
15. Polariscope.
16. Landscape colours.
17. " cameras.
18. Shadow phenomena.
19. Kinematograph for eclipse.
20. " " shadow.
21. Contact observations.
22. Observations on natives, animals, &c.

The observers were as follows :—

1. *Time Signals.*
Captain A. W. Chisholm-Batten, R.N.
F. Downton, Leading Seaman.
W. Woods, Yeoman of Signals.
W. Groves, Shipwright.
F. T. Marey, Private, R.M.L.I.
G. S. Fullilove, Private, R.M.L.I.
G. Cleary, Private, R.M.L.I.

2. *6-inch Prismatic Camera.*
Mr. Fowler.
Lieutenant O. de Wett, R.N.
C. Ironsides, G.M.
J. Turner, T.I.
F. Brading, A.B.
J. Innes, A.B.
G. Salt, Boy, 1st Class.

3. *9-inch Prismatic Camera.*
Dr. Lockyer.
Lieutenant Percival-Jones, R.N.R.
A. Ramage, A.B.
W. Bray, Ch. Arm.
A. Wilkins, Shipwright.
E. Ashford, A.B.
F. Fenton, A.B.
A. Carr, Boy, 1st Class.

4. *Integrating Spectroscope.*
Lieutenant G. C. Quayle, R.N.
J. Bird, Ch. E.R.A.
G. Travill, P.O., 1st Class.

5. *6-inch Equatorial with Grating Spectroscope.*
Sir Norman Lockyer, K.C.B.
Professor A. Pedler, F.R.S.
Mr. R. C. Steele, Gunner, R.N.
P. Ross, Ch. E.R.A.
G. Vanstone, Ch. E.R.A.
H. Brown, Ship's Steward's boy.

6. *Coronagraph.*

Staff-Engineer A. Kerr, R.N.
W. Holmes, E R.A.
C. Moseley, Leading Stoker, 1st Class.
G. Collier, Stoker.

7. *Discs.*

A. Ruse, Ship's Corporal, 1st Class.
G. Pink, Qualified Signalman.
J. Henry, Boy, 1st Class.

B. Brook, Stoker.
A. McDonald, P.O., 1st Class.
A. Tull, Ship's Steward's Boy.

L. Pettingale, Leading Signalman.
W. Brooker, A.B.
S. Drew, Ordinary Seaman.

R. Sutherland, Leading Signalman.
W. Webb, A.B.
W. Corney, Stoker.

G. Price, A.B.
J. Jones, A.B.
F. Dibbins, Ordinary Seaman.

L. Gates, A.B.
R. Davis, A.B.
P. McKenna, A.B.

8. *Sketches of Corona without Discs.*

General.
A. Richardson, P.O., 1st Class.
W. Pankhurst, A.B.
H. Lack, Boy, 1st Class.

N.E.
W. Anderson, A.B.
E. Wilson, Ordinary Seaman.

N.W.
T. Wells, A.B.
H. Brinstead, A.B.

S.E.
E. Dann.
W. Evans.

S.W.
W. Clayton.
A. Penny.

9. *3¾-inch Equatorial.*

Sir Norman Lockyer, K.C.B.
Mr. H. Willmore, Assistant Engineer, R.N.
M. Moore, Stoker.

10. *Observations on Stars.*

Lieutenant Henry Blackett, R.N.
J. McDonald, A.B.
F. Stevens, A.B.
R. Buckland, Plumber's Mate.
T. Sutton, Stoker.
J. Fitzroy, Boy, 1st Class.
G. Russell, Private, R.M.L.I.

11. *Observations of Shadow-bands.*

Staff-Surgeon C. L. Nolan, R.N.
C. Hester, Private, R.M.L.I.
A. Purkington, 2nd S. B. Steward.

12. *Meteorological Observations.*

Mr. John Eliot, C.I.E., F.R.S.
J. Russell, Chief Stoker.
C. Butt, Leading Stoker, 1st Class.
H. Rockett, Stoker.
A. Wallace, Stoker.
G. Pratt, Stoker.
H. Wallburn, Stoker.
J. Bartlett, Stoker.
T. McCarthy, Stoker.
E. Perry, Stoker.
G. Woolston, Stoker.
G. Garrard, Stoker.
C. Mintram, Stoker.
P. Keefe, P.O., 1st Class.

13. *Hand Spectroscopes.*

Lieutenant C. E. B. Colbeck, R.N.
C. Kitchingham, Private, R.M.L.I.
C. Woodley, P.O., 1st Class.
P. Manning, Ordinary Seaman.
H. Mitchell, Stoker.
J. Dobson, Sergeant, R.M.L.I.

14. ***Prisms for Observations of Ring Spectra.***
    - Mr. J. Mountifield, Senior Engineer, R.N.
    - W. Morris, E.R.A.
    - A. Howe, E.R.A.
    - C. Stacey, Leading Stoker, 2nd Class.
    - H. Knight, Leading Stoker, 2nd Class.
    - R. Coates, Stoker.
    - G. Tarrant, Stoker.
    - H. Warren, Stoker.
    - J. Inch, Stoker.
    - G. Gray, Chief Stoker.
    - J. Cross, Stoker.

15. ***Polariscope.***
    - Staff-Surgeon C. L. Nolan, R.N.

16. ***Landscape Colours.***
    - Lieutenant E. N. R. Dugmore, R.N.
    - G. Farrell, Boy, 1st Class.
    - W. Jacobs, A.B.
    - P. Darvil, Boy, 1st Class.
    - H. Rhodes, Ordinary Seaman.
    - H. Attree, Signalman.

17. ***Landscape Cameras.***
    - Mr. Turner, Survey Department, Calcutta.
    - E. Gyngell, A.B.
    - H. Childs, Chief Stoker.
    - J. Collins, Chief Stoker.
    - J. Kearney, Leading Stoker, 1st Class.
    - E. Cross, Leading Stoker, 2nd Class.

18. ***Shadow Phenomena.***
    - W. Keenan, Chief Carpenter's Mate.
    - A. Reynolds, Stoker.
    - W. Weeks, Shipwright.
    - G. Riley, Stoker.
    - B. Crunden, Stoker.
    - C. Carpenter, Stoker.

19. ***Kinematograph for Eclipse.***
    - The Marquis of Graham.
    - A. Shilcock, E.R.A.
    - E. Green, Boy, 1st Class.
    - C. Thomas, Seedie.
    - P. King, Ordinary Seaman.
    - W. Cronen, Stoker.

20. ***Kinematograph for Shadow.***
    - Mr. H. P. Barnett, Paymaster, R.N.
    - A. Gidney, E.R.A.

21. ***Contact Observations.***
    - Lieutenant O. de Wet, R.N.
    - C. Ironsides, G.M.

22. ***Observations on Natives, Animals, &c.***
    - W. J. C. Slocombe, Ordinary Seaman.
    - G. Whittingstall, Ordinary Seaman.
    - F. Beal, Ordinary Seaman.

Aides-de-Camp to Sir Norman Lockyer, K.C.B., F.R.S.
- Mr. W. H. P. Bourne, Midshipman, R.N.
- J. Hunt, P.O., 2nd Class.

The development of the photographic plates was commenced immediately after the eclipse, and it was found that the results were on the whole very satisfactory. No results, however, were obtained with the integrating spectroscope, and the kinematograph films taken by Lord Graham were too badly fogged to serve any useful purpose.

The dismantling of the instruments was commenced very soon after the eclipse, and the packing, together with the development and copying of the negatives, kept the party fully occupied until the morning of January 25, when the expedition left Viziadrug.

Half of the negatives and glass copies of the remainder were conveyed to England in charge of Mr. Fowler, while the remaining half of negatives and positives were sent home *viâ* Bombay.

The general time signals were given by a bugler under Captain Batten's orders. The chronometer was in charge of Lieutenant de Wet, R.N.

For the work of the prismatic cameras it was important to get a signal as nearly as possible five seconds before the beginning of totality, and, in order to eliminate the possible error of the chronometer, it was arranged to determine this by direct observations. Two methods were adopted. In one of them a boat was moored at a distance of two miles from the camp, in the direction of approach of the shadow, which would pass this point five seconds before totality. This failed because of the indefinite boundary of the shadow.

The other method was to determine when the visible remaining crescent subtended an angle of 45°; calculation showed that this would occur at the desired interval from totality. This method was completely successful.

The special signals during totality were given every ten seconds, beginning at 127—the assumed period of totality—by means of the eclipse clock (which was started at the signal "go" by cutting a thread thereby releasing the pendulum), by two timekeepers, one during the first half, the other during the second half of totality.

In the system adopted not only was the time left called out every tenth second, but other signals were interpolated to guide the work in the photographic huts. In order that there might be no mistake about the calls, a spiral was drawn on the clock-face and the seconds left plainly marked at the points which the second hand would occupy during its two revolutions.

In consequence of the perfect drill acquired at the rehearsals the operations went off during the eclipse with absolute steadiness. They commenced about one and a half hours before totality, ending after a like interval after totality. Six volunteers were employed in the timekeeping, including three with lamps which were not wanted.

The Chief Instruments employed.

The Prismatic Cameras.

In the two prismatic cameras no less than fifty-seven photographs were secured, the exposures varying from one to fifty seconds. Such a result as this could only be obtained by a minute subdivision of labour. In the case of each of these two instruments six volunteers were employed, and they were distributed in the following manner:—

One observer with the finder, his duty being to keep the image

in the centre of the field of view which corresponded (by previous adjustment) to the centre of the plate in the prismatic camera. He had a timekeeper to record the times of contact.

A third acted as timekeeper to record the exact moments at which the exposures were begun and ended.

A fourth volunteer, by means of a piece of cardboard, covered and uncovered the front of the prism, from directions given by Mr. Fowler and Dr. Lockyer respectively.

In one case two, and in another three, men were required to hand and receive the large dark slides before and after exposure, taking them out or placing them back in bags made for this purpose.

Six-inch Prismatic Camera.

This instrument, the dispersion of which had been increased this year by the addition of a second prism, was worked by Mr. Fowler, with the assistance of Lieut. de Wet and five men. Mr. Fowler's programme was to begin taking a series of ten snap-shot pictures five seconds before the commencement of totality, to obtain a record every second or thereabouts of the spectrum of the chromosphere. After this he exposed eight other plates to secure photographs of the coronal rings, the exposures being of various lengths. It was also arranged that at five seconds before the end of totality he should commence another series of ten snap-shots, exposing the last of these some few seconds after totality. On developing the plates it was found that everything had gone satisfactorily. The large plates containing the ten snap-shots give the whole story of the chromosphere during twelve seconds, the time to make the ten exposures, and in one of the negatives there are as many as a thousand lines (about).

The last set of ten exposures did not come out quite as expected, for the reason that the duration of totality was a few seconds shorter than had been provided for in the time table, so that only two of the exposures were made before the end of totality. The very last exposure, however, taking about nine seconds after totality, shows many bright lines.

Nine-inch Prismatic Camera.

This instrument was in charge of Dr. W. J. S. Lockyer, who was assisted by Lieut. Percival Jones, R.N.R., and six men. This instrument was also fed by a siderostat, but the tube was not placed horizontally. It was intended with one of the prismatic cameras to so mount the tube that the arcs formed on the photographic plate should be symmetrical about the direction of dispersion, and it was decided that the 9-inch camera should adopt this plan of mounting.

The exact position of the tube to obtain this result was carefully determined by calculation. To facilitate the erection of the instrument at the station two wooden tops to carry the tube were previously made and taken out.

It is satisfactory to state that the photographs showed that the experiment was very successful, the arcs coming out exactly as forecasted.

Although this instrument was capable of only giving about half the dispersion of the 6-inch, the optical parts were better adapted for recording the ultra-violet region of the spectrum.

The programme adopted was similar to that of the 6-inch, there being two large plates ($16 \times 6\frac{1}{2}$) for recording a series of ten snapshots at and near the times of second and third contacts and nine smaller plates for exposure during totality. All the exposures were successfully made, but the lines in the spectrum are not so distinct owing to warping of the wooden tube by the heat and the consequent disturbance of the focus.

I shall refer to the results obtained by the prismatic cameras later in this preliminary report.

Integrating Spectroscope.

This instrument consisted of a large collimator, two prisms of 60°, and a receiving camera. It was entrusted to the care of Lieut. G. C. Quayle, R.N., with two assistants. The light which fed this instrument was obtained from a cœlostat, and there was still sufficient room for another instrument to be utilised, so the coronagraph was set up in the same hut. Although three exposures were made, no results were secured owing, it is feared, to an alteration of the slit, which was found closed after the eclipse.

Six-inch Equatorial with Grating Spectroscope.

This instrument consisted of a 6-inch lens mounted equatorially. The small grating employed contained 17,296 lines to the inch, and in the focus of the eyepiece was placed a small photographic spectrum of iron for comparison.

Professor Pedler, who came to take charge of this instrument was assisted by Mr. Steele, R.N., gunner, and three other volunteers. Up to the present time I have not received Professor Pedler's report of his observations, but I may say that among his observations reported at the time, he recorded the presence of arc lines of iron in the lower corona and the absence of the enhanced lines.

The Coronagraph.

All the more important instruments available for the expedition being employed in the spectroscopic work I could only use a small one for taking photographs of the corona, which were essential for me in order to make comparisons with the chromosphere and coronal rings we hoped to get in the prismatic cameras. The instrument employed, of $4\frac{5}{8}$-inch aperture, was entrusted to Staff-Engineer At Kerr, R.N., who was assisted by three volunteers.

Five photographs were taken. These on development were found to be exceedingly good, the long exposed plate showing a great amount of detail both in the polar rifts and in the streamers.

There being still a small amount of available surface of the cœlostat for other purposes, this was utilised for the 10×8 landscape camera which was operated by Mr. Turner. Two exposures were made during totality, with very successful results. The longest exposure shows very well the general form of the corona and the relative lengths of the extensions, the longest streamer being nearly three lunar diameters.

Discs.

The discs, six in number, were put into position by Lieutenant G. C. Quayle, R.N., and Lieutenant C. E. B. Colbeck, R.N., being ranged along the southern wall of the fort, close to the Eclipse Camp. The great altitude (53°) of the sun rendered the operation of setting them up somewhat difficult. Their sizes varied from six to two inches, and they were so placed that they cut off 3, 5, and 7 minutes of arc round the dark moon.

Each disc occupied the time of three men, so that in all eighteen volunteers were employed. Of each party of three, one volunteer kept the eye end in adjustment up to the time of totality, another who was blindfolded ten minutes before totality acted as observer, and the third wrote down the remarks of the observer.

A preliminary examination of the drawings shows that no equatorial extension was observed.

The $3\frac{1}{4}$-inch Equatorial Telescope.

This telescope was used by me to observe the exact time of second and third contacts to give the signals "go" and "over" to the timekeepers. For the first fifty seconds of totality I employed this instrument myself to minutely observe the structure of the rifts and streamers. In my absence it was used by Assistant Engineer H. H. Willmore for the examination of the structure of the corona.

Observations of Stars during Eclipse.

This party of six volunteers was in charge of Lieutenant Henry Blackett, R.N. Each observer was supplied with a photograph of a small star chart of the region near the sun, prepared by Dr. Lockyer. This was afterwards supplemented by another on a larger scale photographed at the office of the Trigonometrical Branch of the Survey of India at Dehra.

Two striking observations were made by most of the observers. First, more stars were seen just before the commencement of totality than during the actual period of totality; that is, they were logged as disappearing just before the total eclipse phase commenced. A similar observation was made by Admiral Don Ulloa in the eclipse of 1778.* Secondly: two observers noted on the chart a bright body, certainly not a star, midway between the planets Mars and Venus. It was seen only for a short time, and that before totality, being estimated as of the Second Magnitude.

Meteorological Observations.

Mr. Eliot, the Meteorological Reporter to the Government of India, brought with him several important instruments with a view of making observations similar to those he had arranged along the whole line of totality. The report of his observations I have not yet received. He was assisted by twelve volunteers.

Observations of Shadow Bands.

Staff-Surgeon Nolan, R.N., observed these phenomena with the help of two assistants. Previous to the eclipse a large white tablecloth was spread on a flat piece of ground in front of two walls intersecting at an angle of 115°, which were whitewashed. The bands were well seen before the second and after the third contact. None were seen during totality. Their direction of travelling was before totality towards the west (N. 88° W.), veering gradually round to S. 60° W. After totality they practically reversed their direction, travelling N. 60° E. They moved too quickly for their rate of motion to be determined, but it was noted that their rate of motion was not constant.

They were estimated to be about ½ to 1½ inches in breadth, but this also varied. The interspaces were gauged at 4 to 6 inches in breadth.

Each observer noted, one minute after totality, a long intermittency during which a large band, about 2 inches broad, passed by itself in a most striking manner.

* 'Phil. Trans.,' 1779, p. 105.

The Chief Results bearing on Solar Theory.

1. *The Spectrum of the Chromosphere.*

Considerable time must elapse before the complete discussion of the numerous photographs taken in the prismatic cameras can be completed. I therefore give here only some general results which can be gathered by a preliminary inspection of them.

I first deal with the determination of the heights of the various absorbing vapours so far as they can be gathered from the photographs, which, of course, only record for us the brightest lower portions of the different arcs, and not their complete extension.

The following table shows the results obtained in the case of some of the most typical lines:—

Lines.	Length of arcs.	Height.	
		In miles.	In secs. of arc.
Ca(K)	130°	6000	13·3
Hydrogen	112°	4500	10·0
He 4471·25	105°	4000	8·9
He 4026·3; Sr 4077·9, 4215·66	86°	2700	6·0
Ca 4226·9; Unknown, 4247 / Mg ultra-violet triplet	72½°	2000	4·4
Fe triplet (4045) / Strongest arc lines (4307·96, 4325·92, &c.) / Al 3944·16 and 3961·67	60°	1450	3·2
Fe enhanced lines 4584, 4233 / Mn quartet (4030·9, &c.)	51°	1100	2·4
Fe enhanced quartet (4523·0, &c.) and many other lines	40°	650	1·4
Carbon fluting and many lines, including arc lines of iron	35°	475	1·05

A very noticeable feature of the chromospheric spectra, which the photographs enable us to investigate at different elevations, is the difference in the behaviour of the gaseous and metallic lines. In the spectrum taken very near the moment of second contact, representing that of the lower strata with the spectra of higher ones superposed, the metallic arcs are relatively short and very bright, while in later photographs, representing the spectra of successively higher strata free from admixture with lower ones, the metallic arcs are relatively feeble. This is also indicated in another way by the varying effects seen over the tops of lunar mountains and through indentations in the moon's limb.

Some of the lines are seen to be relatively much brighter in the

upper strata than in the lower, such lines showing no notable increase of brightness at the points where lower strata are revealed through lunar valleys. Chief among these lines are those of hydrogen, helium, and calcium (H and K), but there is an additional line at wave-length 4686·2 or thereabouts, which behaves in the same way.

This line does not appear in Young's list of chromospheric lines and all attempts to trace it in known spectra have failed. A line apparently coincident with it, however, has been found in the photographed spectrum of a tube containing helium, which is one of a series of comparison spectra being taken with the 6-inch prismatic camera to facilitate the reduction of the eclipse photographs.

The only recognised impurity in the vacuum tube used is oxygen, but besides the line to which reference has been made, there are a few faint lines for which no origins can at present be assigned.

It is worthy of remark that this line falls very near to the first line of the principal series in the spectrum of hydrogen, recently calculated by Rydberg to have a wave-length of 4687·88.*

As in the case of the photographs taken with the prismatic cameras in 1893 and 1896, the spectrum of the chromosphere in 1898 is very different from the Fraunhofer spectrum, so that we have not to deal with a mere reversal of the dark lines of ordinary sunlight into bright ones. (See fig. 1, next page.)

Many very strong chromospheric lines, as the helium lines for example, are not represented among the Fraunhofer lines, while many Fraunhöfer lines are absent from the chromospheric spectrum.

2. *The Spectrum of the Corona.*

The heights of the chief coronal rings as photographed are roughly as follows:—

1474 K	60,000 miles (in lower parts of inner corona).
3987·4	20,000 miles.
4231·3	More than 10,000 miles.

The coronal rings not only differ from the chromospheric ones in regard to the heights to which they extend above the photosphere, but also in appearance.

The outlines of these rings are distinctly not connected with the configuration of the chromosphere and prominences. In photographs taken near the beginning and end of totality, the 1474 ring is brightest on the same side of the moon, although the chromosphere and prominences are first visible on one side and then on the other. None of the rings give any indications of increased brightness at the places occupied by prominences. The green ring, corresponding to

* 'Astro. Phys. Jour.,' vol. 6, p. 237.

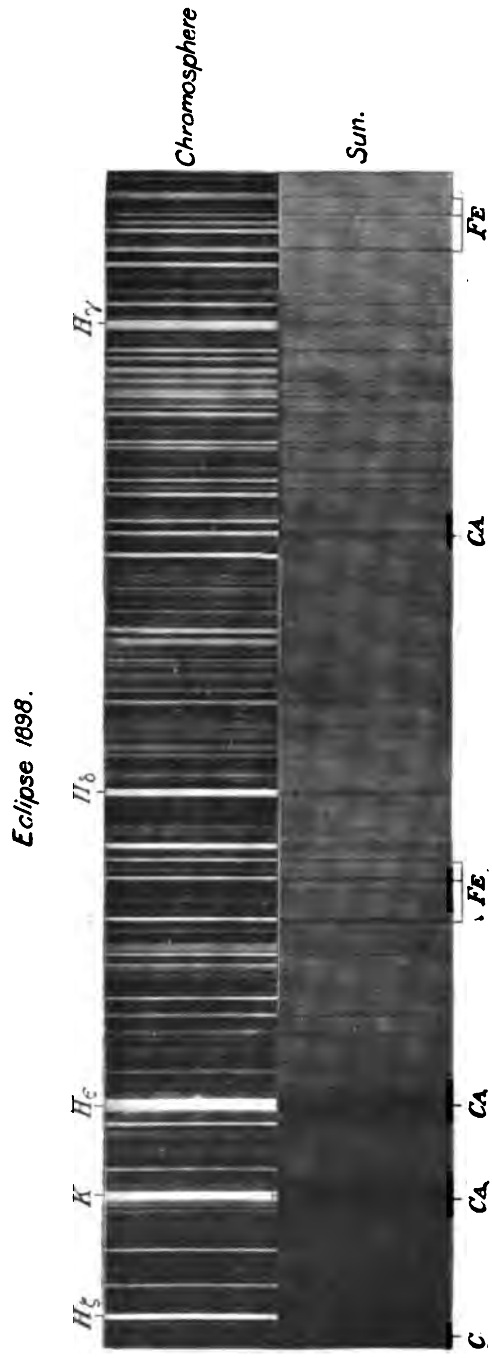


FIG. 1.—Spectrum of Chromosphere as photographed during Eclipse compared with Fraunhöfer lines.

1474 K, which is the brightest of the rings seen, can be traced completely round the limb, and while in some parts it is very feeble, in others it is bright enough to show the brightest projections of the inner corona as photographed with short exposures with the coronagraph. The other rings at 3987 and 4231 can also be traced completely round the limb, but they are fainter on the average and of much more uniform intensity than 1474 K. This latter fact suggests that the additional rings are produced by a substance which is not the same as that to which 1474 K corresponds.

It is interesting to note that the three rings photographed in 1898 were also the most conspicuous in the coronas of 1893 and 1896 as determined by the use of prismatic cameras. The following table gives a comparison of the results obtained in the three eclipses, the wave-lengths for 1898 of course being only provisional.

1893.	1896.	1898.
3987	3988	3987·4
4086	4084	
4217		
4231	4232·0	4231·3
4240		
4280		
4486		
5316·9	5316·9	5316·9

3. *Results regarding the Corona.*

I looked forward to the corona this year with the greatest interest on account of the high temperature of the sun as judged by the fact that scarcely any iron lines have been recorded as most widened in the spectrum of sun spots since the end of 1892; that is, chemically, the maximum sun-spot conditions have been retained since 1893. Hence I was not astonished to see several large spots on the sun on the days preceding the eclipse.

I pointed out in 1878, a year of minimum, that the corona of that year was vastly different from that of 1871, a year of maximum; not only was it very much dimmer, but its spectrum was continuous; there were practically no bright lines, while long equatorial extensions were seen.

Normally we should have expected an approach to the 1878 conditions this year. But both the photographs and eye observations show that the only minimum appearance noticeable was the exquisite tracery near the sun's poles.

The violent magnetic storm and bright aurora on March 15 and 16,

to which Mr. Chree has recently called attention, follow suit with the chemical and eclipse observations, and it is important to note, as Dr. Chree has informed me in a later communication, that there were less violent disturbances on January 15—18 and February 11—16, so that there have been three disturbances separated roughly by an interval of twenty-eight days.

Conclusion.

The extraordinary interest and the skill displayed by the officers and men of H.M.S. "Volage" under Captain King Hall in 1896, and of H.M.S. "Melpomene" under Captain Chisholm Batten in the present year, prove beyond all question that in eclipses in which a man-of-war can be employed the most effective and the most economical means of securing observations is to depend upon the naval personnel, one or two skilled observers being sent out to help in the final adjustments of instruments according to the number it is intended to employ.

At Viziadrug, Mr. Fowler and Dr. Lockyer were enabled to report all the fixed instruments and huts, eight in number, erected and all but the final adjustments made after six days' work, a long break being necessary in the middle of the day in consequence of the heat. Such an achievement as this is beyond all eclipse precedent and was only rendered possible by the help of a large staff of highly trained men. Of the 150 engaged in the operations only three originally formed the expedition.

It is, therefore, quite inappropriate that I, on the part of the expedition, should here tender thanks to Captain Batten, the officers and men of H.M.S. "Melpomene" for their assistance, for as matters turned out we assisted them; but we are anxious to place on record the kindness we received from them both afloat and ashore, and since the great success of the recent observations is due almost entirely to Captain Chisholm Batten and the ship's company of the "Melpomene," I trust that the President and Council of the Royal Society may be pleased to communicate this fact to the Lords Commissioners of the Admiralty.

Among those to whom thanks are specially due are the following representing the Indian Government:—

E. Giles, Esq., Director of Public Instruction, in charge of arrangements made by Bombay Government.
K. R. Bomanji, Esq., Collector of Ratnagiri.
J. L. Jenkins, Esq., Collector of Salt.
E. H. Aitken, Esq., Assistant Collector of Salt.
F. R. Bader, Esq., Assistant Engineer, P.W.D.

Gangadhar Anant Bhat, Executive Engineer, P.W.D.
Govind Goshi, Overseer, P.W.D.
Sadashi Govind Joshi, Clerk to the Overseer, P.W.D.

Thanks are also due to the Officers of the Police, Telegraph, and Customs Departments, and others representing the Bombay Government, for their unceasing efforts to help us in every way.

Everybody was struck by the admirable and smart manner in which the subordinates of the Public Works Department accomplished their respective tasks.

I took upon myself when leaving Viziadrug, to write an unofficial letter to Mr. Bomanji, thanking him, in the name of the expedition, for his great personal kindnesses to us as well as for the valuable assistance we had received from him and the other local representatives of the Government.

L. Lee, Esq., Collector of Customs for Ceylon, and other Customs officials at Colombo rendered valuable assistance to the expedition by granting special facilities and providing means for transhipping the instruments.

The Orient Steam Navigation Company very kindly conveyed the instruments free of charge to and from Colombo.

To W. H. Sinclair, Esq., a former Collector of the district (now retired), I was indebted for the supply of much valuable local information before leaving England.

My own personal thanks are due to Mr. Fowler and Dr. Lockyer, who assisted me in the preliminary work of organisation, and who, while at Viziadrug, worked hard both day and night to further the objects of the expedition; and also to Mr. Bourne, Midshipman, attached to me as Aide-de-camp, who was indefatigable in helping me to carry out the various details of the local organisation.

"Total Solar Eclipse of 1898, January 22. Preliminary Report on the Observations made at Pulgaon, India." By Captain E. H. HILLS, R.E., and H. F. NEWALL, Sec. R.A.S.

Received May 25, 1898.

(PLATES 9, 10.)

CONTENTS.

I. *Origin of the Expedition and General Preparations.*

By Captain Hills and H. F. Newall.

This expedition was one of those organised by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee.

The observers are indebted to the Great Indian Peninsular Railway Company for the carriage of the instruments at reduced rates between Bombay and Pulgaon, and for a considerable reduction of fares to the observers for this journey.

Observers.—The party consisted of :—

> *Captain E. H. Hills, R.E.*, Instructor in Chemistry and Photography at the School of Military Engineering, Chatham.
> *H. F. Newall, Sec. R.A.S.*, Cambridge Observatory.

(In what follows these will be designated by the initials H. and N.)

It had originally been arranged that Dr. E. J. Stone, Radcliffe Observer, Oxford, should be a member of the party. The vacancy caused by his lamented death was not filled, as it was decided to use the skilled assistance which could be obtained locally in order to carry out part of the programme of work that Dr. Stone intended to attempt, namely the obtaining of twelve photographs of the corona with the double tube camera.

Local Arrangements.—When the preparations were being made for this expedition the Surveyor-General of India intimated that his department would be willing to give what assistance they could. This generous offer was gladly accepted by the Joint Permanent

Eclipse Committee, and the Surveyor-General was asked if he could send—

(*a*) An officer who would take general charge of the camp.

(*b*) Six skilled native assistants.

(*c*) A photographer who would bring with him a suitable dark room ready for erection, and photographic materials.

The officer detailed to take charge of the camp at Pulgaon was Captain G. P. Lenox Conyngham, R.E., and the observers feel that they owe much of the success of the expedition to the excellence of all the arrangements made by him.

The thanks of the observers are also due to Lieut.-Colonel St. G. Gore, R.E., Superintendent of the Trigonometrical Survey, for the continuous interest he took in the work, and to Lieut. G. A. Beazeley, R.E., for much help in the observations, and in the developing and copying of the photographic plates.

The observers are also indebted to the local authorities for their kindness in doing everything that was possible to render the time spent in the Eclipse Camp, both pleasant and profitable, in particular to W. A. Nedham, Esq., Commissioner, Nagpur; S. N. Chitnavis, Esq., Deputy Commissioner, Wardha; and A. C. Blennerhassett, Esq., I.C.S., Assistant Commissioner, Wardha. A number of others, whose names are mentioned below, took part in the actual observations, and the observers wish to express their grateful thanks for the valuable assistance thus rendered.

Selection of Station.—In order that the masonry piers to carry the instruments might be built, and that all the arrangements for forming the camp might be proceeded with before the arrival of the observers it was considered advisable that the choice of the actual station, the approximate position of which had been already decided upon, should be left to the Survey officer in charge. The place selected was Pulgaon, on the Nagpur branch of the Great Indian Peninsular Railway, and the camp and observatory were placed on an open piece of ground about a mile to the north of the station. The position proved excellent in every way.

Arrival at Station.—N. arrived at the camp on January 10, H. on January 12. All the instruments, which had been forwarded direct from Bombay, had previously arrived, and the necessary piers and huts for the observatory were found completed in accordance with the plans prepared and sent by the observers to Captain Lenox Conyngham. It was thus possible at once to proceed with the erection and adjustment of the instruments.

Meteorological Observations.—A continuous set of meteorological observations were made from January 16 to January 23, of which it may be interesting to give a summary.

	Wind.	Barometer.			Temperature in shade.								Maximum in sun.	Minimum on grass.
					Dry bulb.			Wet bulb.			Max.	Min.		
		9 A.M.	12 NOON.	3 P.M.	9 A.M.	12 NOON.	3 P.M.	9 A.M.	12 NOON.	3 P.M.				
Jan. 16	Very light, N. to N.W. ..	29·2	29·4	29·2	66	90	88	58	72	67	95	44	110	42
„ 17	Very light, E. to N.	29·2	29·3	29·2	68	87	89	58	69	69	95	43	110	39
„ 18	Calm	29·2	29·4	29·3	65	86	92	56	69	73	93	41	109	37
„ 19	Calm	29·3	29·4	29·3	63	83	86	58	66	66	89	40	105	36
„ 20	Calm to very light, S.E...	29·2	29·3	29·2	64	82	86	55	65	69	90	43	106	39
„ 21	Calm to light, S.E.	29·2	29·3	29·2	65	86	90	57	69	71	94	46	110	42
„ 22	Calm	29·2	*	29·2	69	90	88	59	73	71	92	45	107	41
„ 23	Calm	29·3	29·3	29·3	70	86	93	62	67	74	96	48	113	43

* Eclipse day. Barometer not read at noon.

Total rainfall, nil. Total cloud amount, nil.
The instruments employed were standard ones by Negretti and Zambra.

It is interesting to compare these figures with those given by Mr. Eliot in his meteorological note prepared in connection with the eclipse. No data are given for Pulgaon, but the conditions are practically the same as those found at the two nearest stations for which the figures are given, namely Akola and Nagpur.

We have then—

	Temperature.			Cloud amount (parts in 10).		Rain-fall.
	Max.	Min.	Daily range.	10 A.M.	4 P.M.	
Average at end of January in a few recent years—						in.
Akola	84	53	31	1·00	1·48	0·11
Nagpur	83	55	28	1·41	2·18	0·14
Observed—Pulgaon	93	44	49	Nil	Nil	Nil

The figures exhibit the futility of selecting an eclipse station on meteorological data only.

Departure.—The observers left the camp on January 25.

II. *Totality at Pulgaon.*

By Captain Hills and H. F. Newall.

The preparations for totality as regards the instruction and drilling of the assistants calls for little mention. The skilled native assistants, provided by the kindness of the Surveyor-General, were thoroughly accustomed to observing work, and the preparations and preliminary drills proceeded with the utmost smoothness.

The two men selected as timekeepers were instructed to call out the seconds from the beats of a metronome, which had been previously carefully rated.

The signal for the beginning of totality was given by Captain Lenox Conyngham who was making the exposures with the double tube camera, but it was also necessary for the spectroscopic work to get a signal at some definite time before totality which was accomplished by the following method:—

The length of the diminishing crescent of the sun was calculated for 15 seconds before totality. The observer in charge of the double tube camera watched the image on his ground glass and gave a signal when the crescent had arrived at the calculated length. The actual interval between the 15 second signal and the beginning of totality was 13 seconds.

Observing Party.—The following is a complete list of the whole observing party :—

Double Tube Camera.

In charge of instrument—Captain G. P. Lenox Conyngham, R.E.
Exposer—Babu S. C. Goha.
Recorder—Babu S. N. Saha.
Handing slides—Kali Din.
Receiving ditto—Mahabri.
Holding bags—Balgar.

Spectroscopic Cameras.

Observer—Captain E. H. Hills, R.E.
Exposer—Quartz spectroscope, Lieutenant F. R. H. Eustace, R.E.
,, —Flint spectroscope, Babu I. C. Dev.
Assistant in charge of slow motion—Lieutenant G. A. Beazeley, R.E.
Recorder—Mrs. Hills.

Spectroscope with Two Slits.

Observer—Mr. H. F. Newall.
Assistants—Mrs. Newall, Babu S. B. Shome.

Grating Spectroscope.

Observer—Mr. H. F. Newall.
Assistant—Mr. A. C. Blennerhassett, I.C.S.

Time Keepers.

Sub-Assistant Superintendent Hanuman Prasad.
Babu Lal Singh.

Recording Thermometers.

Captain G. C. Kemp, R.E.

Observing Magnetometer.

Lieut.-Colonel St. G. Gore, R.E.

Photographing Shadow Bands.

Mr. J. Harrold.

Recording Contacts.

1st and 4th—Captain Hills, R.E.
2nd—Captain G. P. Lenox Conyngham, R.E.
3rd—Mr. E. Batchelor, I.C.S.

Observed Times of Contacts.

Pulgaon—Latitude, 20° 44′ 10″·6 N.
Longitude, 78° 19′ 2″·5 E.

Computed distance from centre line, 4 miles.

The observed local mean times of contacts were :—

1st......	11 hrs.	50 min.	43·0 secs.
2nd	13 „	21 „	3·0 „
3rd	13 „	22 „	58·0 „
4th	14 „	43 „	54·5 „

The chronometer employed was rated by theodolite observations, and was probably correct within 1 sec.

Temperature Observations.—The result of the observations made for the two hours about totality were as follows :—

L.M.T.	In sun.		In shade.		
	Black bulb.	Glass bulb.	Dry bulb.	Wet bulb.	
h. m.					
12 21	99	93	90	73	
12 36	94	93	87	70	
12 51	90	90	85	69	
13 6	84	84	83	67	
13 21	79	78	80	66	Commencement of totality.
13 23	77	77	79	66	End of totality.
13 31	75	74	78	66	Lowest readings.
13 46	81	82	78	67	
14 1	89	86	82	67	
14 16	93	90	85	68	
14 31	97	94	86	69	

Magnetometer.—Colonel Gore made observations with the magnetometer with a view of detecting variation in the horizontal component of the earth's magnetic field during the eclipse. No change was observed.

Shadow Bands.—An attempt was made to photograph these with a small camera provided with an excellent Cooke lens of large aperture (F/6·3). A white sheet was stretched opposite to the sun's position, and a series of exposures was made at beginning and end of totality. Several spectators saw shadow bands, but no trace is discoverable on the photographs.

III.—*The Double-tube Camera.*

By Capt. Hills.

Instrument.—This camera was the one used by Mr. Taylor in Brazil in 1893, and was taken to Norway by Dr. Common in 1896. The tube is of wood, 6 feet long, and 14 × 7 inches in section, divided

by a partition into two square tubes of 7 × 7-inch section. In one of these was placed the "Abney" lens of 4 inches aperture and 5 feet 2 inches focal length, giving an image of the sun 0·57 inch in diameter; in the other the photoheliograph objective (used in Transit of Venus expedition), of 4 inches aperture and 5 feet focal length, with a Dallmeyer secondary magnifier of 7½ inches focus placed 5 inches within the focus, the combination giving an image of the sun 1½ inches in diameter. The camera was furnished with six plate-holders, each taking two plates of 160 × 160 mm., as in use for the astrographic chart, both plates being exposed by a quarter-turn of one shutter. The camera was pointed to a 16-inch plane mirror, made by Dr. Common, and mounted as a cœlostat by Mr. Hammersley after a design by Dr. Common, the sun's rays being thus reflected into the telescope.

The camera and cœlostat were not placed in a hut, but a screen of bamboo matting was erected round the whole instrument, to protect it from the wind, to which the cœlostat is particularly sensitive. Another portion of bamboo screen was placed horizontally above the camera, to protect the observer and the wooden body of the camera from the direct rays of the sun.

Mounting and Adjustment.—The cœlostat was placed on a masonry pier level with the ground. As some trouble had previously been experienced with the driving clock, owing to the heavy weight necessary, care was taken on this occasion that it should be very rigidly fixed in position. The method adopted was to screw the clock down on to a stout wooden base-board, which in its turn was firmly bolted to the masonry pier carrying the cœlostat, the driving cord being led off horizontally under one pulley attached to the base-board, and over another pulley hanging from the top of a strong wooden trestle about 6 feet high. Railway fishplates were used as weights. With this method no trouble at all was experienced, and the clock-driving was irreproachable.

In order to carry the camera, two parallel brick walls were built on the west side of the cœlostat, and on the top of each of these a 4-feet length of heavy rail was placed, held in ordinary railway chairs, lent for the purpose by the railway authorities at Pulgaon. A wooden stop or button fixed on the under side of the camera rested against the lower rail and prevented the camera from slipping down towards the mirror.

The angle at which the camera was set was so selected that the slide end should be at a suitable height for working. It was found convenient to direct the camera towards a point about 30° below the horizon, a little to the south of east. The focussing was done by reflection, and calls for no special remark, the final adjustment being accomplished by using the cœlostat mirror.

The adjustment of the axis of the cœlostat was effected very quickly by means of the attached declination theodolite. The level attached to the telescope makes it possible to adjust in altitude without any astronomical observation, for the latitude of the place can be taken from the map with sufficient accuracy; and setting the telescope to the south declination equal to the co-latitude, and in the meridian, the level should indicate horizontality. Index errors of the circle and level are eliminated by reversal of the instrument. There is a slight uncertainty attending the placing of the telescope in the meridian, but this does not seriously affect the adjustment in altitude. If a cross-level were made for the pivots of the telescope, this uncertainty could be removed.

To adjust in azimuth we must have an observation of the sun (or a star) at a distance from the meridian. Observing his declination (in reversed positions of the instrument and taking the mean), the instrument must be moved in azimuth until this observed declination agrees with that given in the 'Nautical Almanac.' A very few trials, if the sun can be seen for half an hour, will soon indicate the true azimuth without any calculations, within a minute or two of arc, though if the instrument be moved much in azimuth the altitude observation must be repeated.

After the initial adjustment of the cœlostat it was not disturbed, but the adjustment was re-tested at intervals, with the following results. The individual readings were only taken to minutes of arc, but both limbs of the sun were observed in both positions of the instrument, and the mean of the four set down :—

Cœlostat. Observer H.

Date.	Hour angle of sun. hrs.	Observed decl.	Tabular decl.	O.—C.
Jan. 15........	−3·0	21° 7′	21° 7′	0′
16........	−3·0	20 55	20 56	−1
17........	+2·0	20 40	20 42	−2
19........	−2·5	20 18	20 20	−2
20........	+3·0	20 6	20 7	−1

From this general watch kept on the instrument it is clear that the adjustments remained good within 1′ or 2′, which is more than sufficient for the purpose. The only other adjustment required is the setting of the face of the mirror parallel to the polar axis of the instrument. This was easily effected by reversing the mirror in the Ys and observing if the sun's image in the two cases crossed the same position on the ground glass when the mirror was moved in right ascension.

Three screws are provided in the base of the mirror cell for correcting this error should any be found.

Programme of Observations.—The six slides were filled and intended to be exposed as follows:—

No. of slide.	Exposure.	Plate.
1	2 secs.	Ilford "Empress."
2	8 „	Ditto, ditto.
3	12 „	Ditto, Special Rapid.
4	24 „	Ditto, ditto.
5	12 „	Ditto, "Empress."
6	4 „	Ditto, ditto.

Plates 2, 3, 4, 5 were backed with a solution of asphalte in benzol and had the Abney standard squares impressed on them. If the rapidity of the Special Rapid be taken as twice that of the Empress plates, the above programme gives a series of equivalent exposures of

2, 4, 8, 12, 24, 48 seconds.

No exposures of less than 2 seconds were made, because it was considered that the detail of the inner corona would be better shown by the large scale pictures, of which at least four separate sets were being taken by independent observers at other stations.

The orientation of the corona was determined by the following method: After the last exposure had been completed the clock was stopped and the whole instrument was left untouched, with the slide still in the camera, till night. The Abney lens was then uncovered for about 2¾ hours, the mirror being left stationary, and a series of star trails were thereby drawn across the plate.

A recorder was employed whose duty was to note the exact time of each exposure made during the eclipse. They were as follows:—

Slide No.	Exposure according to programme.	Actual exposure.		
		Shutter opened.	Shutter closed.	Duration.
		Beginning of	totality = zero.	
	secs.	min. sec.	min. sec.	sec.
1	2	0 5·0	0 7·5	2·5
2	8	0 14·0	0 22·0	8·0
3	12	0 27·5	0 39·0	11·5
4	24	0 47·0	1 11·0	24·0
5	12	1 18·5	1 30·5	12·0
6	4	1 37·0	1 41·0	4·0

All the above plates were successfully developed the night after the eclipse, and positive copies on glass were made to guard against loss.

A reproduction of one of the best photographs (No. 3, Dallmeyer lens, 12 secs. exposure), is given in Plate 1 (frontispiece).

IV.—*The Spectroscopic Cameras.*

By Capt. Hills.

Instruments.—The details of the two spectroscopes used were as follows:—

	Spectroscope No. 1.	Spectroscope No. 2.
Objective	Cooke achromatic, $4\frac{1}{2}$ in. aperture, 5 ft. 10 in. focus.	Single quartz lens, 5 in. aperture, 4 ft. 9 in. focus.
Collimator and camera lenses.	Single quartz lens, $2\frac{1}{2}$ in. aperture, 30 in. focus.	Single quartz lens, 3 in. aperture, 36 in. focus.
Slit	$1\frac{1}{2}$ in. by 0·0018 in.	2 in. by 0·0014 in.
Prisms	Two dense flint prisms of 60°, $4\frac{1}{2}$ in. base, $2\frac{1}{2}$ in. height.	Four double quartz prisms of 60° (each prism being composed of two half-prisms of right- and left-handed quartz), $3\frac{1}{2}$ in. base, $2\frac{3}{4}$ n. height.
Prisms at min. deviation for	H_γ.	H_ϵ.
Position of slit with respect to sun's image.	Parallel to meridian through sun's centre, cutting limb at point of second contact.	Vertically diametral.

The slits were in each case adjusted to such a width as to realise one-seventh of the theoretical maximum resolving power of the prisms. In the case of spectroscope No. 1 which, as will be shortly seen, was used for most of the work, this amounted to about 0·3 of an Angström unit in the violet. It may be noted that any higher degree of resolving power would have been wasted owing to the coarseness of grain of the photographic plate, the above figure representing not only the calculated resolving power of the instrument, but that actually realised on a trial plate.

The length of the spectrum on the plate was $3\frac{1}{4}$ inches from H_β to K.

Both spectroscopes were mounted in an approximately horizontal position, and were supplied with light by a heliostat, furnished with a 12-inch flat mirror.

Erection and adjustment of Instrument.—The heliostat and spectroscopes were placed on masonry piers, and a hut of bamboo matting was built up round the latter. The heliostat was left in the open, and, such was the dryness of the air, that it was found that a sheet tied over it at night was more than sufficient to protect it from any damp.

The adjustment of the polar axis of the heliostat was carried out by means of an attached theodolite in precisely the same manner as has been described above in the case of the cœlostat. As it was not possible to reverse the instrument when the slow motion in right ascension was attached, the position of the axis when once adjusted was not retested. This, however, was of little importance, as great accuracy in the driving is not required for this work.

The adjustments of the spectroscopes call for no special mention.

Programme of Exposures.—Two separate lines of work were undertaken :—

(1) The recording of the spectrum of the corona—using for this purpose both spectroscopes, and giving only one exposure of as long a duration as possible.

(2) The recording of the "flash" or spectrum of the sun's limb at both the beginning and end of totality.

For this purpose, spectroscope No. 1 only was used, the camera being provided with a sliding plate, by which means a large number of successive exposures could be made at short intervals.

It was intended to begin the exposures about 10 seconds before second contact, and to continue them till 7 seconds after it, and to expose a similar series at third contact.

In order to get the latter series, it was necessary to shift the image on the slit, which was done by the slow motion of the heliostat, an assistant being stationed at the latter, watching the sun through the theodolite telescope attached to the polar axis.

All the available time during totality, was employed in the long exposure for the corona spectrum.

The complete programme of exposures as drawn up, was as follows, the expected duration of totality being 115 seconds :—

Spectroscope.	No. of slide.	Exposures.	Time in totality.	Plate.
No. 1...	1	10 of 1 sec.	-10 to $+7$ secs.	Lumière "green sensitive."
	2	1 of 85 secs.	15 to 100 secs.	" " "
	3	10 of 1 sec.	108 to 125 secs.	" " "
No. 2...	1	1 of 98 secs.	7 to 105 secs.	Ilford Special Rapid.

All the essential points of this programme were carried out The actual time of each exposure was as accurately as can be ascertained,

2nd contact:	−10, −8, −6, −4, −2, 0, +2, +4, +6, +8, seconds.				
3rd „	−3, −1, +1, +3, +5, +8, +10, seconds.				
Corona:	Spectroscope No. 1.	Exposed	79	seconds from	21−100.
„	„ No. 2.	„	98	„ „	7−105.

The second series did not begin quite as soon as had been intended, and between the fifth and sixth exposures there was rather a longer interval than between the others, owing to a slight mistake on the part of the exposer. This is, however, of no consequence, as all the interest centres about the photographs taken within 5 seconds of the contact.

The Corona Spectrum.—A reproduction of the corona spectrum as obtained by the two-prism flint spectroscope is given in Plate 2. It is obvious that the photographic intensity of the continuous spectrum fell off very rapidly on receding from the limb. No trace of it is seen at a greater distance than 4′.

Five strong bright lines of unquestionably coronal origin are to be seen. Their wave-lengths, and relative intensities may be provisionally given as—

λ (Rowland).	Photographic intensity.
3987·0	5
4233·5	10
4360·0	3
4567·9	8
5316·9	8

There are other fainter lines whose wave-lengths have not yet been determined.

Spectroscope No. 2, with the quartz train, gave a corona spectrum stretching a considerable distance into the ultra-violet, but of feeble intensity. A strong bright line occurs at λ 3801·0, and the lines given above are also to be plainly seen with the exception of the well known line in the green which was outside the plate.

Spectrum of the limb.—The two series of spectra of the limb contain an immense amount of detail, and will take a considerable time for complete examination. As an indication of the character of the results obtained, reproductions of portions of the two spectra taken at second and third contacts are given in Plate 3.

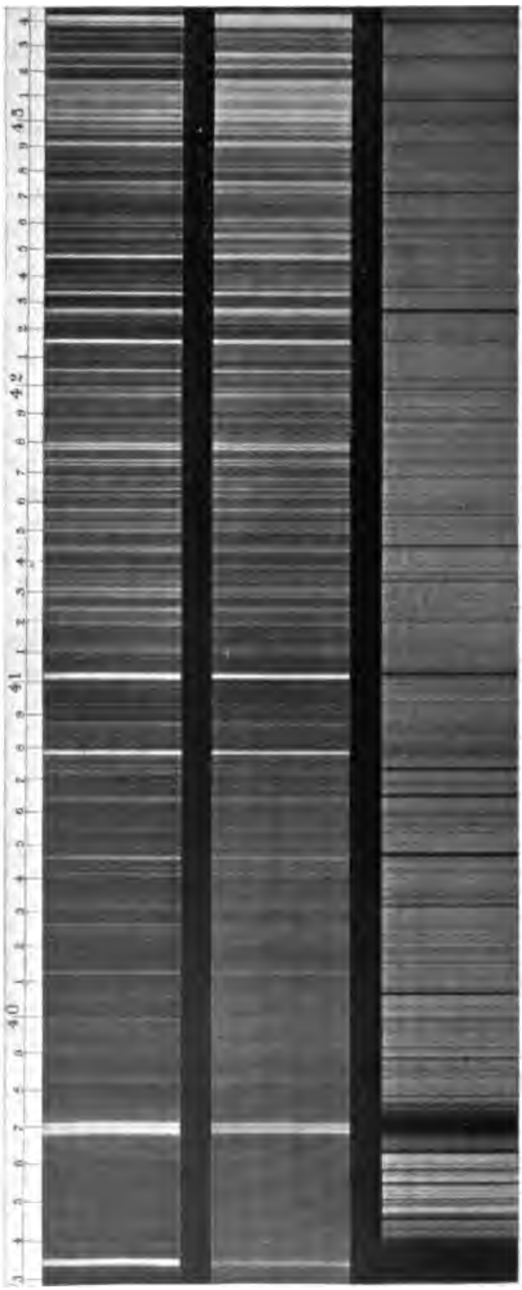
As considerable interest attaches to the question of the connection between the bright line spectrum of the limb and the solar spectrum, a reproduction of the latter, taken with the same instrument is appended.

CORONA SPECTRUM.

From photograph taken with a 2-prism flint spectroscope, at Pulgaon, by Captain E. H. Hills, R.E. Enlarged 1¼ times.

SPECTRUM OF SUN'S LIMB.

(Region H, to K.)



From photographs taken with a 2-prism flint spectroscope, at Pulgaon, by Captain E. H. Hills, R.E. Enlarged 3¼ times.

V.—*The Spectroscope with Two Slits.*

By H. F. Newall.

It was intended to attempt (i) to determine by a spectrographic method, the difference in velocity in the line of sight in the eastern and western equatorial regions of the corona, (ii) to utilize the same material, as was obtained for the first research, for a comparison of the spectra of widely separated parts of the corona, and (iii) to use the same instrument in securing photographs of the bright line spectrum of the sun's limb at the end of totality, to be used for the accurate determination of the wave-lengths of the bright lines.

The instrument provided for these purposes is a four-prism spectroscope with two slits.

The train of prisms is of such dimensions and construction, as to transmit a 2-inch beam of light, and to produce a minimum deviation of 180° for H_γ. The collimator and camera are set parallel to one another.

The whole spectroscope is mounted so as to turn about an axis, parallel to the collimator. The axis is rotated (with a period of 24 hours) by clockwork, and is tilted so as to be parallel to the earth's axis. In this position the collimator points to the north pole.

The tube of the collimator is prolonged beyond the plane of the slit, and is arranged to carry at its end a mirror of speculum metal and an object glass, by means of which an image of the sun can be thrown upon the slit.

The whole arrangement thus consists of a spectroscope combined with a polar heliostat, and in virtue of the fact that the spectroscope is rotated together with the mirror, the image of any celestial object thrown upon the slit does not rotate relatively to the slit. Furthermore, the mirror is mounted in such a manner that the axis about which it can be tilted—namely the declination axis—can be oriented relatively to the collimator tube, so that any diameter of the sun may be set parallel to the slit.

The two slits with which the collimator is provided are parallel to one another in the focal plane of the collimator lens, and are separated by such a distance that when the image of the eclipsed sun is thrown between the slits, one is illuminated by the eastern, the other by the western equatorial region of the corona. The top half of one slit is covered, and also the bottom half of the other. The exposures for the two sides of the corona are made simultaneously, and the resulting photograph should give two spectra side by side on the same plate, one slightly displaced, relatively to the other, by an amount depending on the separation of the two slits and the construction and adjustments of the spectroscope.

It was decided that certain coronal lines in the neighbourhood of

λ 4233 would be the best available for the determination of displacement due to velocity.

The linear dispersion in the photographed spectrum is about 15 tenthmetres per millimetre at H_γ. The relation between the velocity in the line of sight and one complete revolution of the micrometer to be used in the measuring the plate is about 260 kilometres per second for one revolution.

The scale of the photograph is such that one degree on the sky corresponds to about 9 mm. on the plate.

The effective aperture of the combination regarded as an instrument for producing monochromatic images of a slit-shaped region of the corona is $\frac{1}{15}$.

The adjustment of the axis of the instrument to parallelism with the earth's axis, was accomplished in the same manner as that adopted for adjusting the cœlostat. A theodolite with declination circle was attached to a part of the frame of the spectroscope, specially prepared for it, between the camera and the collimator. The adjustment was very easily and satisfactorily made: in altitude by observations made with the spirit level attached to the theodolite-telescope, and in azimuth by observations of the sun made some hours before or after noon.

Programme of Exposures and General Results.

I. *Spectra of the Corona.*—A set of five photographs, from which the relative velocity in the line of sight of the eastern and western equatorial regions of the corona could be deduced, was to be taken with the spectroscope with two slits.

The programme of exposures was carried out completely successfully, as follows:—

Thirty minutes before totality, plate A was exposed for 15 seconds for spectra of sunlight diffused from the sky near the sun.

Fifteen minutes before totality, plate B was exposed for 20 seconds for a duplicate of plate A taken in falling temperature.

During totality, plate No. 1 was exposed for 100 seconds for the spectra of the eastern and western regions of the corona.

Fifteen minutes after totality, plate C was exposed for 15 seconds for spectra of sunlight diffused from the sky near the sun.

Thirty minutes after totality, plate D was exposed for 15 seconds for a duplicate of plate C under different temperature conditions.

Result.—On development, the photographic plate No. 1 showed no trace of any impress of the coronal spectra, though the development was pressed as far as possible.

It is clear that the failure is due to the faintness of the corona in the region photographed. Captain Hills was successful in photo-

graphing the spectrum of the corona at the same station, but the radial extension of the bright lines and also of the continuous spectrum is unexpectedly small. In neither of his photographs is the spectrum traçeable further than about 4′ from the limb of the sun. N., basing his attempt on the results obtained by Deslandres in 1893 and by Abney and Thorpe, had tried to photograph the spectrum at nearly 8′ from the limb of the sun. The apparatus used on the present occasion was of such design and construction, that it was expected to give considerably brighter images than those used by Deslandres in 1893.

II. *Spectrum of the Sun's Limb.*—With the same spectroscope, photographs were to be taken of the bright line spectrum of the sun's limb at the end of totality.

Ten seconds before the end of totality, the exposure referred to in the preceding paragraph was completed; and whilst another plate-holder was being placed in the camera of the spectroscope, the adjustments in R.A. and Declination were changed so that the image of the chromosphere, which was being disclosed near the point of third contact, was adjusted on one of the two slits. Four exposures were then made in rapid succession.

Results.—The photographs thus obtained, give spectra ranging from about $\lambda\,3900$ to $\lambda\,4900$; and the first of the series contains a vast number of bright lines, generally similar to those seen in Captain Hills' photographs, and to those shown in the photograph obtained by Mr. Shackleton in Novaya Zemlya, 1896, August 9, and reproduced in Sir Norman Lockyer's Preliminary Report,* and also to those obtained by Mr. Fowler in 1893, and reproduced in Sir Norman Lockyer's Report.†

An additional point of interest in the first photograph of the series is that many absorption lines are also visible. A cursory comparison with the solar spectrum discloses the interesting fact that these lines differ in intensity from the absorption lines in the ordinary solar spectrum.

VI. *The Objective Grating Telescope.*

By H. F. Newall.

An objective grating telescope was used for visual observations of the coronal ring in the green light of wave-length 5316·9 (1474 K).

A plane grating, by Rowland, 14,438 lines to the inch on a ruled surface, $3\frac{1}{2} \times 2\frac{1}{8}$ inches, was fixed on a turn-table in front of a telescope of focal length 29 inches and aperture $3\frac{1}{2}$ inches. A positive eye-piece was used which gave a magnifying power of 19·2, and whose circular field of view was rather more than 1° in diameter.

* 'Phil. Trans.,' A, vol. 189 (1897), pp. 259—263.

† *Ibid.*, A, vol. 187 (1896), Plate 14.

The instrument was mounted so that the telescope was parallel to the earth's axis and pointed towards the north pole. The grating was used in a manner analogous to that in which the mirror of a polar heliostat is used. The light of the corona was incident on the grating at an angle of about 57°, and diffracted beam utilised in the telescope left the grating at an angle of about 13°. In this position of the grating, the green of the second order was used, and the magnifying power of the grating was a little greater than $\frac{1}{2}$, so that the distorted coronal ring was an ellipse, in which the major axis was about twice as great as the minor axis; the minor axis was parallel to the length of the spectrum and perpendicular to the direction of daily motion. No clockwork was used, but a slow motion of a very simple construction was provided and found to work perfectly satisfactorily. The observations were begun 6 seconds after the beginning of totality, and were completed in about 70 seconds.

Results.—The coronal ring was seen in the spectrum of the second order with great distinctness and with such brilliancy as to leave no doubt that it could have been photographed.

None of the fine radial structure of the corona could be seen, though it was especially looked for; but broad patches of light were clearly visible in different positions round the ring.

A drawing of the brighter extensions was made during the eclipse, the observer (N.) keeping himself intentionally in ignorance of the orientation of the image seen in the eye-piece until after the observations were completed so as to avoid bias. A preliminary comparison of the drawing with the direct photographs of the corona has been made, and the following general statements will probably not require much revision on a closer comparison :—

(i) There appeared to be glowing "Coronium" (assuming that the radiation of wave-length 5316·9 is rightly attributed to an element "coronium") at all points round the sun's limb extending radially to distances estimated as ranging between 4′ and 14′.

(ii) The luminosity was not uniform round the limb, but in no position was it entirely absent.

(iii) No *fine* radial streamers comparable with those seen near the poles of the sun in ordinary direct photographs of the corona were observed, though this fine structure was specially looked for.

(iv) In certain positions round the limb patches of increased luminosity were seen; in all, seven patches were noted; in several cases the extension was considerably greater in a radial direction than in a tangential. The bases of the

broad streamers on the limb subtended angles ranging from 10° to 30° at the centre of the sun's disc, and the radial extension in three cases was estimated as being greater than 12′.

(v) Two of the long streamers referred to in the last paragraph were found to coincide roughly in position with marked broad extensions in the direct photographs of the corona, viz., that to the N.E. and that to the S.W. But the third long streamer to the N. seems to have no connection with any obvious extension in the photographs.

(vi) There was no marked "coronium" luminosity corresponding either to the double-rayed extension in the N.W. quadrant or to the broad extension in the S.E. quadrant.

(vii) As far as it has been possible to pursue the investigation at present, there has appeared no relation between the position of the brighter patches of coronium and the prominences, except perhaps near the three prominences in the N.W. quadrant.

VII. *Polariscopic Observations.*

By H. F. Newall.

It was intended to devote any time that remained over, after providing for the three foregoing investigations during the eclipse, to (i) a search for faint extensions of the corona with the aid of a polariscope, or as an alternative (ii) a general investigation of the nature of the polarisation-phenomena visible during an eclipse. It was expected that results obtained in the latter investigation would probably only be serviceable in suggesting methods of research for future eclipses.

The polariscope used consists of a Nicol prism with a Savart plate attached in front of it. The field of view of the instrument is lozenge-shaped after the manner of Nicol prisms, the long axis being 29° long and the short axis 24°. The width of the central band due to the Savart plate was approximately 1° 25′ between the centres of the first lateral dark bands, the centre being regarded as that part of the dark band where the dusky red meets the steel blue. The plate had been adjusted relatively to the Nicol prism, so that the bands when visible were parallel to the principal plane of the Nicol, and they were kept in this relative position throughout the observations. The instrument was used without telescope or circles.

Observations.—When first the instrument was put to the eye, about 85 secs. after the beginning of totality, bands were visible over the whole field of sky seen through the Nicol prism. Not only were the alternations of brightness seen, but the colours of the bands appeared

with unexpected vividness. They were seen at all points within 30° of the sun, with little or no variation in vividness, and as the instrument happened first to be held, the bands were approximately parallel to the sun's axis. These vivid bands are attributed to the polarisation of the light scattered (diffracted) by solid particles in the earth's atmosphere.

The bands were so disconcertingly vivid that a few moments were wasted in inspection of the instrument, but immediately afterwards observations were quietly renewed, the search for faint coronal extensions was abandoned, and attention was confined to the phenomena of polarisation.

The instrument was rotated about its axis, and the bands faded from view and became invisible in a certain position. It was thought immediately after the eclipse that the observations made were enough to prove that the plane of polarisation was neither vertical nor horizontal, but it has since been found that the evidence is not such as to warrant this statement. When the bands had become invisible in the outer part of the field of view, the rotation of the instrument was discontinued for a moment. The eye then gradually became aware of faint colours over the corona, but the distribution appeared to be uneven—rather in patches than in bands. These colours are attributed to the polarisation proper of the corona. The "patchy" distribution is doubtless a result of the nature (presumably radial) of the polarisation of the corona, and of the largeness of the scale of the bands compared with the diameter of the moon (1° 25′ : 33′). The fact that the colours appeared faint in contrast with the vivid sky-bands previously seen may be referred to several alternative explanations which cannot well be dealt with here in detail. It is obvious that the ratio of the brightness of the light scattered by the sky to that of the light of the corona plays as important a part as the proportion of the coronal light that may be regarded as polarised.

Next, attention was directed to the corona near the limb, and the central part of the central band was observed while the instrument was rotated, the central band being kept radial to the sun's disc. The observed central part was seen to be bright at all points round the limb on the east side, whether the central sky-band were bright or dark.

Then the bands were set so that one of the first dark lateral bands was tolerably close to the moon's limb, with its centre perhaps half a moon's diameter from the limb. The band was observed to be bright near the limb, and to be dark at a short distance on either side.

Both of the last mentioned observations point to the idea that the light scattered by the atmosphere was comparable in brightness with the corona at points not far distant from the sun's limb.

The incompleteness of the observations is recognised, but on the whole it would appear that their suggestiveness justified the observer in devoting 15 seconds to making them.

The observed intensity of the bands, attributed to sky polarisation, is evidence of the quantity of light reflected by solid particles in the atmosphere. It seems not improbable that the unexpected brightness of the general sky and landscape during totality may have been connected with the amount of light reflected from the dust suspended in the atmosphere and illuminated by the sun-lit plains outside the moon's shadow. The light colouring of the plains, due to the dried herbage at that time of year, is very marked at Pulgaon, but it must not be forgotten that the "sun-lit plains" were in the moon's penumbral shadow for more than an hour both before and after totality.

The observations occupied the 15 seconds, ending 15 seconds before the end of totality.

About 30 seconds after the end of totality, polarisation was again looked for, but no trace could be detected near the sun in any position of the instrument.

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